METALSMITH 3c & 2c

NAVY TRAINING COURSES

NAVPERS 10133

METALSMITH 3c and 2c

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PREFACE

This book, the first ever provided especially for Navy Metalsmiths, is written as an aid in preparing for promotion to Metalsmith 3c and Metalsmith 2c. While it is directed primarily toward the men assigned to fighting ships, it is equally valuable to the men in shore billets.

Qualifications for Metalsmith 3c and 2c are listed at the back of this book. To meet some of these qualifications, you may need to use some of the BASIC NAVY TRAINING COURSES, particularly the three entitled *Mathematics, Use of Blueprints,* and *Use of Tools.* The *General Training Course for Petty Officers 3c and Petty Officers 2c and* the *Bluejacket's Manual* will also help you in meeting some of the more general qualifications.

After a short explanation of your duties as a Metalsmith, this course gives you helpful information on sheet metal work, welding equipment, gas welding, arc welding, brazing, forging, piping work, and coppersmithing. Other chapters describe the properties, characteristics, uses, and heat treatment of both ferrous and non-ferrous metals and alloys. Special practice jobs are suggested for sheet metal work and welding. The last two chapters deal with firefighting and damage control.

As one of the NAVY TRAINING COURSES, this book was prepared by the Training Courses Section of the Bureau of Naval Personnel.

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CHAPTER 1

THE METALSMITH'S WORK

IT'S INTERESTING!

As a Metalsmith you won't get bored with your work—there's plenty of variety. You may be welding a casting in the morning, flanging a pipe in the afternoon, and building a storage locker the next day. You'll have jobs that call for brazing, or forging, or oxyacetylene cutting. You'll deal with many kinds of metals. This VARIETY of work calls for a wide range of both SKILL and "KNOW-HOW." When you go up for advancement in rating, you'll be tested on both of these qualities. The qualifications for Metalsmith 3c and 2c, given in the back of this book, list skill as PRACTICAL FACTORS and "know-how" as EXAMINATION SUBJECTS.

This book will aid you in developing this ability and knowledge. It contains a great deal of information and numerous PRACTICE JOBS. This course, however, does not give you ALL the background you need. Such jobs as blueprint reading, soldering, pipe threading, layout work, and use of tools—together with the fundamentals of mathematics and the principles of machines—are covered in these BASIC NAVY TRAINING COURSES—

MATHEMATICS	NAVPERS 10620
USE OF BLUEPRINTS	NAVPERS 10621
USE OF TOOLS	NAVPERS 10623
MACHINES	NAVPERS 10625

If you don't have these courses, ask your educational or divisional officer for them. You can pass your tests without reading the *MACHINES* book, but you'll want to look it over for your own information. It explains the principles of construction and operation of many parts of the machines and equipment you'll use and repair.

In addition to reading these basic books, and any others about metalwork that may be available, ask plenty of questions. Other Metalsmiths will help you and answer your questions. They're also glad to check and criticise your practice welding and other practice jobs.

Get all the practice you can. Use your spare time to the best advantage. Prepare yourself so that you will be able to handle ANY metalworking job that might be required of you as a Metalsmith.

SHIPBOARD ORGANIZATION

Metalsmiths are ordinarily assigned to the ship's ENGINEERING DEPARTMENT. The ENGINEERING OFFICER is the head of this department, which usually has four DIVISIONS—

"B"—boilers and steam.
"E"—electrical equipment.
"A"—auxiliary equipment.
"M"—machinery (propulsion).

Metalsmiths are normally placed in the "A" Division. This division is essentially a repair and mantenance party. About three-fourths of its members are Machinist's Mates. The other one-fourth is made up mostly of Metalsmiths. The Machinist's Mates operate and maintain auxiliary equipment such as pumps, valves, and engines. They also make repairs which involve the use of shop machines such as lathes, shapers, grinders, and milling machines. Other repair work—especially that which involves cutting, shaping, forming, welding, brazing, and riveting metal—is the responsbility of the Metalsmiths.

On some ships, Metalsmiths are assigned to the "R" Division of the Hull Department (C&R) and work with Shipfitters and Carpenter's Mates under the direction of

the Chief Carpenter who, in turn, is responsible to the First Lieutenant.

YOUR BAILIWICK

Aboard ship your working station is ordinarily a shop located somewhere in the machinery spaces. The size of the shop, and the amount of equipment it contains, depends largely on the size of the ship.

If you're on a destroyer, you may have only a locker and a tool box, and you'll do your work in any available space. On a light cruiser you'll have a small shop, or share a shop with other rates of your department. On a large cruiser, aircraft carrier, battleship, transport, repair ship or tender, you'll have more space in which to work. Plenty of equipment is available.

On the larger ships your work is directed and supervised by Chief and 1c Metalsmiths. On smaller ships you're pretty much on your own.

Many Metalsmiths are stationed at shore establishments, both in the United States and at advance bases. Others are assigned to repair ships, to special ship repair units, and to amphibious units which repair landing craft.

DAMAGE CONTROL

The skills you learn and use as a Metalsmith make you a valuable man for DAMAGE CONTROL WORK. Usually your battle station is somewhere in the machinery spaces with one of the DAMAGE CONTROL PARTIES. This assignment requires that you be a good EMERGENCY REPAIRMAN and a good FIRE FIGHTER.

Damage control is your most important duty. In fact, practically all of your routine work is either damage CONTROL or damage PREVENTION. And the importance of such work is greatly magnified when your ship suffers severe damage from battle or from collision or other action.

Remember when, early in World War II, the light cruiser *Marblehead* took two 500-pound aerial bombs on her bow and one on her stern? That ship was in bad shape—bow torn apart, 23 compartments flooded, rudder locked in a hard-over position, and enemy planes overhead. But she was saved to fight again—saved largely because of her excellent DAMAGE CONTROL ORGANIZATION. Her repair parties KNEW THEIR STUFF.

The Metalsmiths of the *Marblehead* were right in there doing their share. They helped put the fires out, get the rudder back in commission, clear the wreckage, plug the holes, and shore up the bulkheads. And, when the ship was put in a precarious, undersized, makeshift drydock in a Java port, the Metalsmiths turned to and helped weld up the bashed-in bow. The Navy recognized outstanding work done by the men and officers of that ship. The Navy Cross and other decorations were awarded as a result of the work and courage which kept the gallant *Marblehead* afloat.

LOOKING AHEAD

Always look ahead. When you have mastered all the information in this book and in the basic books, soaked up a lot of "know-how" from other men, and got some practice done, you've laid the foundation for becoming an expert Metalsmith. With the foundation well established, it's easy to keep adding to it by MORE STUDY and by the WORK EXPERIENCES you'll have.

Keep up to date on your work. Keep practicing. Practice most the kind of work in which you are weakest. Get your tests passed. Then, when a desirable billet opens up, you'll be "Johnny on the spot."

CHAPTER 2

SHEET METAL WORK

WHAT YOU WILL DO

When a sheet metal duct needs to be repaired or a new locker made, you're the man for the job. And when the Machinist's Mates need drip pans, funnels, tool boxes, parts, trays, or cabinets, you may be the man assigned to make them.

Higher rated petty officers may draw the plans and lay out the work on the sheet, but as a Metalsmith 3c or 2c, you'll usually do the actual work on the metal—cutting, forming, seaming, assembling, and fastening. And sometimes you may have the job of drawing the plans and laying out the work, too.

You'll work with sheets made of black iron, galvanized iron or steel, aluminum, monel, copper-nickel, corrosion-resisting steel, copper, brass, zinc, tin plate, and terne plate. The uses and properties of the ferrous metals (iron and steel) are set forth in Chapter 12. Non-ferrous metals (those other than iron and steel) are described in Chapter 14.

Sheet metal is tricky stuff to work with, especially when you're bending or forming it. You'll learn mostly by experience how much and in what way you can bend and form the various kinds of sheet material. You'll also

learn to be extremely careful when you handle sheet metal edges, because it's easy to cut your fingers. It's a good policy always to dress (smooth) a freshly cut metal edge with a file.

You'll use many of the hand tools described in the *Use of Tools* book. You'll also use the drill presses and portable power drills which are discussed in that book. Whenever necessary, additional tools are explained and illustrated in this book.

Now take a look at some of the other equipment you'll use—shears, stakes, punches, rotary machines, bar fold-

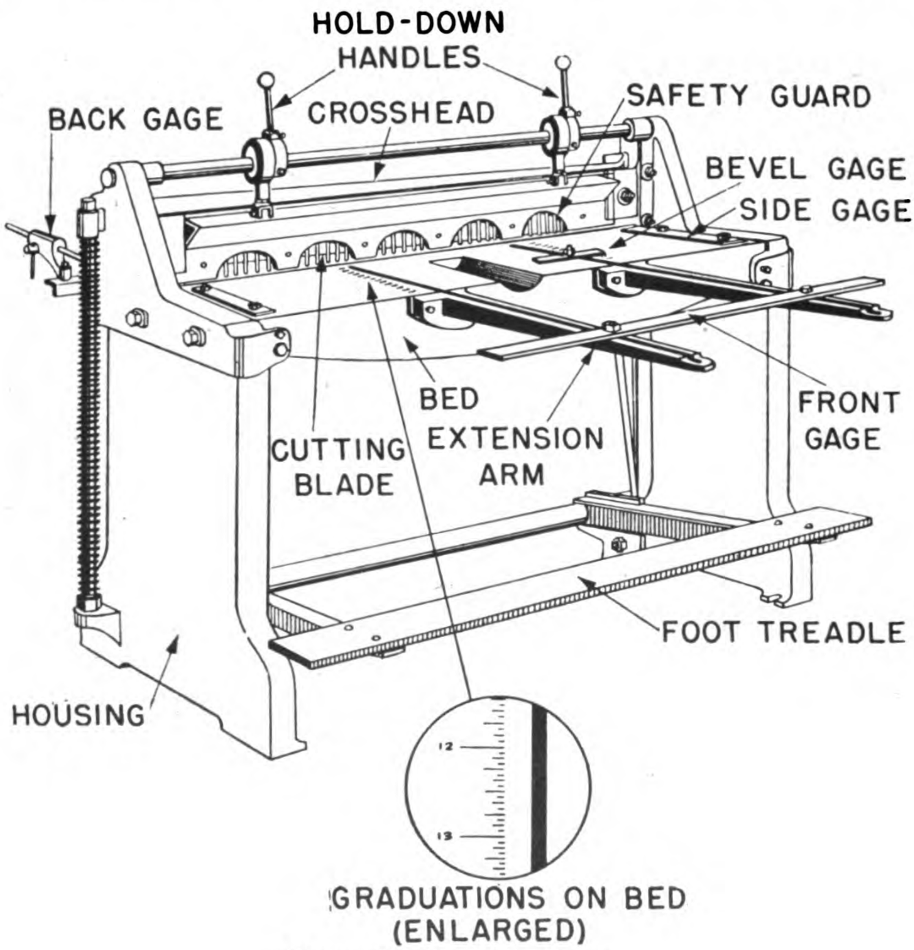


Figure 1.—Squaring shears.

ers, brakes, and slip-roll formers. These machines are designed to be used ONLY on sheet metal and will do a good job if they are not overloaded.

METAL CUTTING MACHINES

The SQUARING SHEARS are used to make straight cuts in

metal sheets. Large shops have huge, heavy, gap shears which slice through quarter-inch plate with the greatest of ease. You will probably have a treadle-operated shear, like that in figure 1, with a capacity of 16 gage ($1/16''$) metal. DON'T try to cut sheets heavier than $1/16$ inch on this machine or you may damage the blade and spring the bed and frame out of shape. And don't cut corrosion-resisting steel with these shears—it's too tough for them.

Adjustable GAGES are provided both in front and behind the cutting blade. Side gages or fences are bolted onto the bed surface at each side. The side gages are set at right angles (90°) to the shearing blade. Use them when you need to square up a sheet. The gages are most useful when you're cutting parts all the same size and shape.

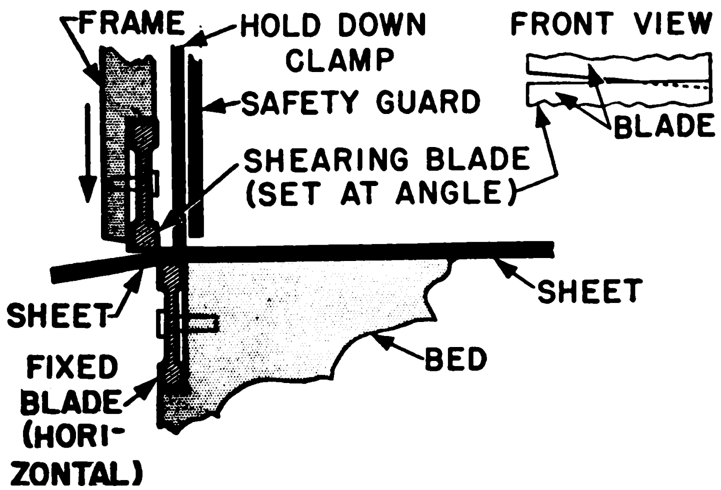


Figure 2.—Principle of the shear.

Notice that a SAFETY GUARD is mounted in front of the blade. It's there to keep you from absent-mindedly shearing off some of your fingers. DON'T EVER REMOVE THIS GUARD. Older shears may not have a guard. If you use an unguarded machine, it's up to you to keep your fingers out of the way.

Notice also the HOLD-DOWN CLAMP. It's operated by the hold-down handles and it clamps the metal sheet securely against the bed so the blade can cut accurately and smoothly. Figure 2 illustrates the principle of the shear.

Metal rules and other tools should never be left on the shear bed. They might slide under the blade and dull it or spring some of the shear parts. And besides that, a rule or square that's cut in two has lost its usefulness.

A UNISHEAR (figure 3) is used to cut sheet metal curves and notches, as well as for straight line cutting. Unishears might be called power-operated, combination snips. This handy machine has short blades which will cut any sheet metal up to its capacity of 18 gage soft steel. No gage is provided—just follow the layout line.

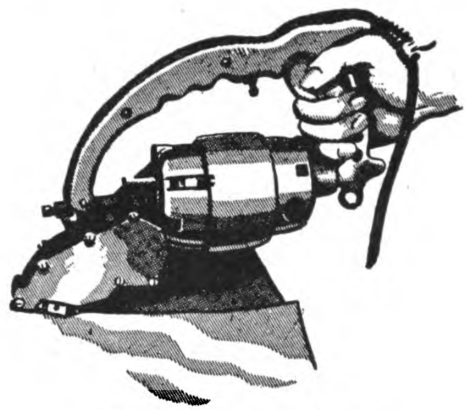


Figure 3.—A unishear.

BAR CUTTERS, NIBBLERS, and BEVERLY SHEARS all work on the same principle as a pair of hand snips. Nibblers and beverly shears are used to cut curves. Bar cutters are used on bars and rods.

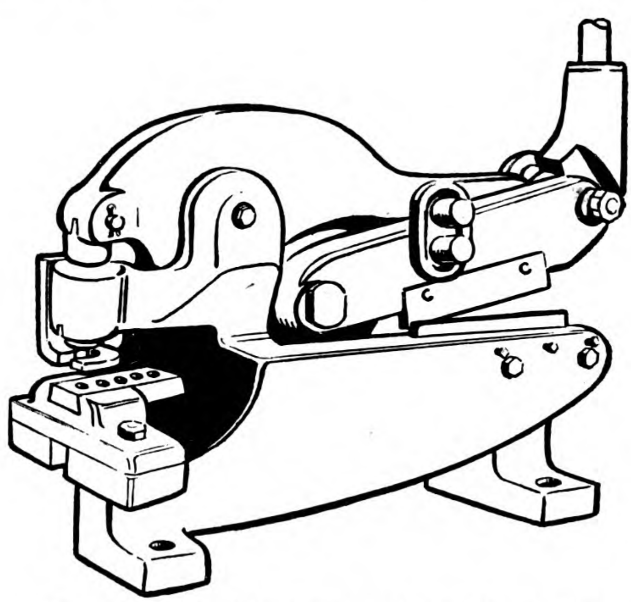


Figure 4.—Combination punch and bar cutter.

The HAND OPERATED PUNCH (figure 4) cuts or shears round holes in sheet metal by means of matching dies. Notice that the punch illustrated here also has a bar-cut-

ting attachment. If your work requires much punching, or if you work at a shore base or on a repair ship, you may be furnished a ROTARY TYPE PUNCH.

CIRCLE SHEARS have two geared disk cutters which are turned by a hand crank or motor. The stock is clamped to a rotating center. This center may be adjusted and set to cut circles to any diameter within the capacity of the machine.

CAPACITY LABELS are usually fastened to the various sheet metal cutting machines. If one of these labels or plates reads CAPACITY 22 GAGE, use it only to cut metal 22 gage and lighter.

Heavy sheet metal or steel plate may be cut with special metal-cutting ("Do-all") band saws and with abrasive cut-off wheels. The oxyacetylene cutting torch is usually used for cutting steel plate, however.

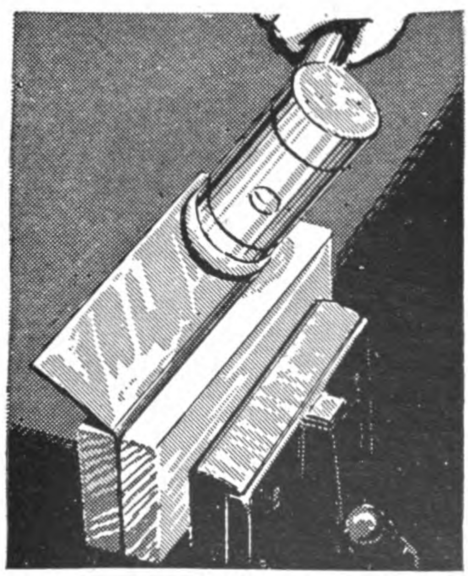


Figure 5.—Bending in a vise.

Don't get the idea that metal cutting machines take the place of hand snips. You'll have plenty of use for snips and other hand tools even if you do have some machines.

FORMING BY HAND

There are many ways to bend and form sheet metal. Machines are usually provided for bending and forming —but a Metalsmith never knows when he may have to get along with ordinary tools and makeshift methods.

Figure 5 shows you how to bend a sheet to form a right angle. The boards are used to protect the sheet metal

which is held in a vise. The edge of one board may be provided with a radius (rounded) so the bend will not be too sharp. The curve of a bend is usually designated by the radius of the curve. The curve itself is commonly called a RADIUS.

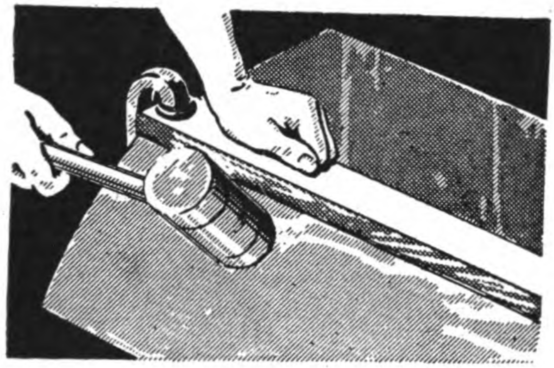


Figure 6.—Forming over a bench top.

You can bend or fold large metal sheets by clamping them to a bench, as shown in figure 6. Just clamp the

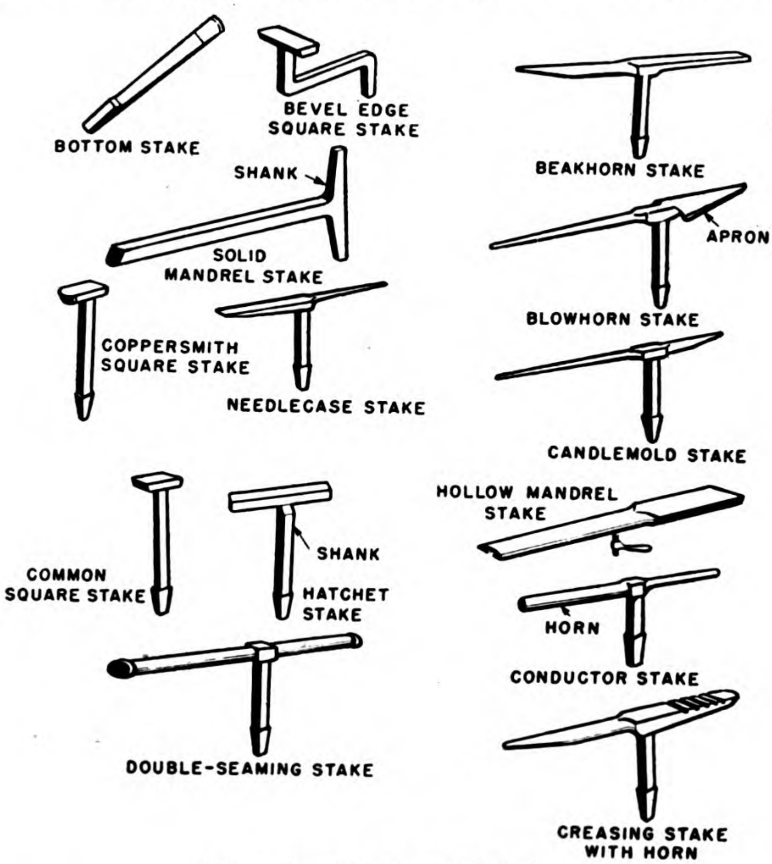


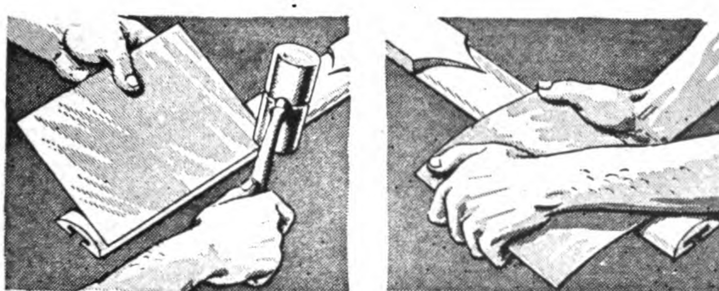
Figure 7.—Sheet metal stakes.

metal in place and force the free end down with your hands. Finish up the job with a mallet.

When sheet metal is bent, the metal on the outside of the bend is stretched—the sharper the bend, the more the metal is strained. This is not an important consideration when you're using metal that is extremely thin and soft. But it is important when you're forming thicker sheets and less ductile metals, because they require a greater bend radius.

STAKES are special bench tools over which sheet metal may be shaped and formed. An assortment of the commonly used stakes is shown in figure 7.

Notice in figure 8*A* how a curve is started over a hollow mandrel stake with a mallet. The curve is finished by hand as shown in *B*.



(A) (B)

Figure 8.—Forming over a hollow mandrel stake.

Conical shapes may be formed over the apron of a blowhorn stake. Figure 9 shows how a funnel body is formed. Care must be taken to keep the curve smooth. Flats and creases will develop unless the metal is kept tight against the stake. For best results, use a rolling, sliding motion.

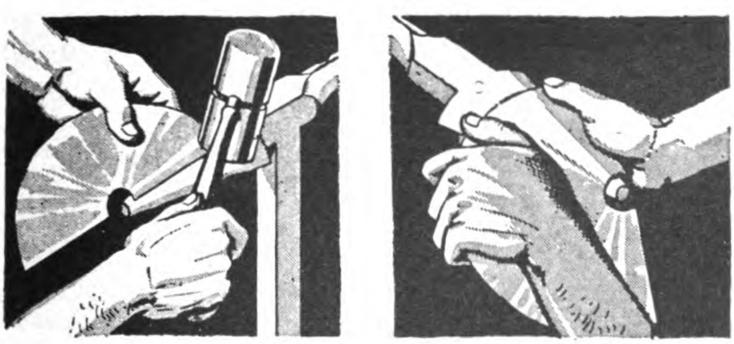


Figure 9.—Forming a cone.

SHEET METAL BRAKES

The cornice brake (figure 10) is a versatile machine for making straight bends or folds in sheet metal. The parts

of the brake which do the actual bending are clearly shown in the circle of the figure.

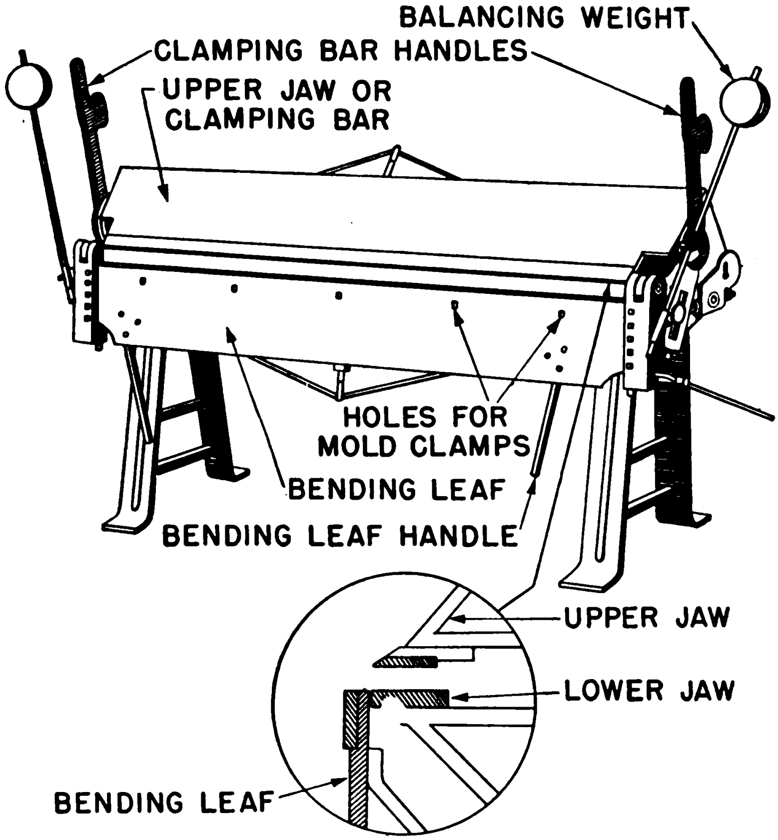


Figure 10.—Cornice brake.

To operate the cornice brake, insert your sheet between the UPPER JAW (the clamping bar) and the LOWER JAW, which is not adjustable. Then clamp the UPPER JAW so that your bend line is directly below the NOSE (front edge) of the beveled upper jaw. After you check the alinement of the bend line, pull up the BENDING LEAF to bend the metal to the desired angle. Most sheet metal springs back about 5 degrees when the bending pressure is relieved so you'll have to move the leaf somewhat more than 90 degrees for a right angle bend. The term SPRING-BACK ALLOWANCE is applied to the additional bending required to obtain the desired angle.

The upper jaw of the brake is the only adjustable part. Move it FORWARD or BACKWARD to regulate the RADIUS (curve) of the bend. The front edge of the upper jaw always should be back of the front edge of the lower jaw a distance at least equal to the thickness of the metal

you're bending. If the distance is exactly equal to the thickness of the metal the bend will be sharp. As you move the upper jaw edge back from the lower jaw edge, the bend radius is increased.

Another method of forming a radius on the cornice brake is shown in figure 11. You can make the mandrel in the shop.

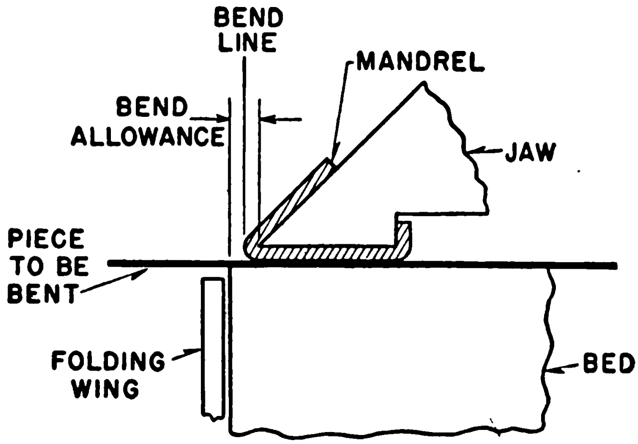


Figure 11.—One method of forming a radius on the cornice brake.

Adjust the upper jaw UP or DOWN to regulate the CLAMPING PRESSURE necessary to hold the stock in place. All jaw-adjusting mechanisms are located at the ends of the brake.

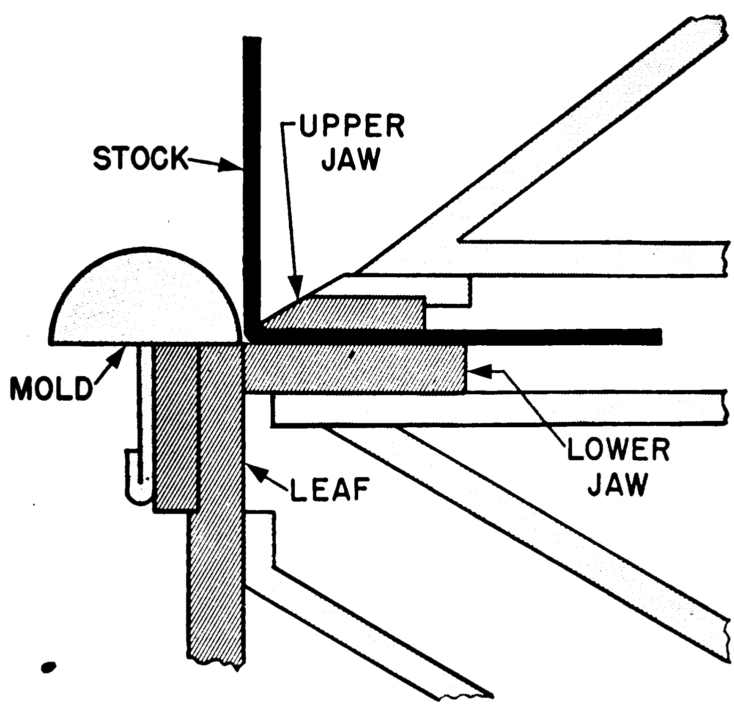


Figure 12.—Job ready to be formed over brake mold.

MOLDS are sometimes furnished with cornice brakes. They are used to form curved sections. The molds are clamped to the folding leaf, as in figure 12. The stock (sheet) is held in the jaws of the brake and formed over the mold by hand. Mold diameters vary from 5/8 to 3 inches.

A BOX and PAN brake (figure 13) is used when the work cannot be handled in a cornice brake. Clamping "fingers" of assorted widths form the front part of the upper jaw. These fingers may be used individually or in groups. The box brake is designed and adjusted the same as a cornice brake, and is used in similar manner.

When you use a box brake, be sure the fingers are firmly clamped in place and that they are fully seated. If the fingers are not properly mounted and secured, they will be damaged, along with the folding leaf.

DO NOT attempt to bend metal that is thicker than the capacity of the brake. NEVER USE A BRAKE TO FORM WIRE, ROD, BAND IRON, OR SPRING-TEMPERED SHEETS. Take good care of the front edges of the upper jaw, fingers, lower jaw and the edge of the leaf.

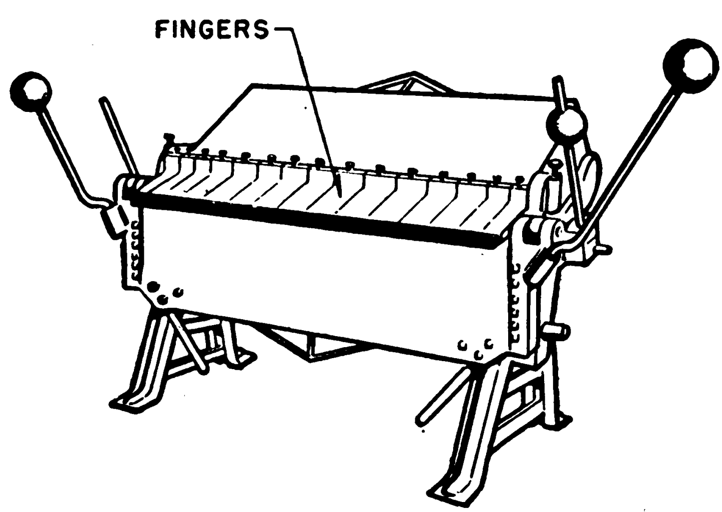


Figure 13.—Box brake.

When you're ready to use a brake, always test your set-up by bending a piece of scrap metal of the same material and thickness as the stock you're using. Few jobs require the same machine setting, so always check the brake before you bend up the job you're working on. Check the RADIUS OF BEND and CLAMPING PRESSURE.

BAR FOLDER

The BAR FOLDER does many of the forming jobs that can be done on a brake but its use is limited to forming EDGES. The average folder will not make a bend or fold more than one inch from the edge of the material. Most bar folders will handle pieces 30 inches long but some have a greater capacity. Small folders have a labeled thickness capacity of 22 gage.

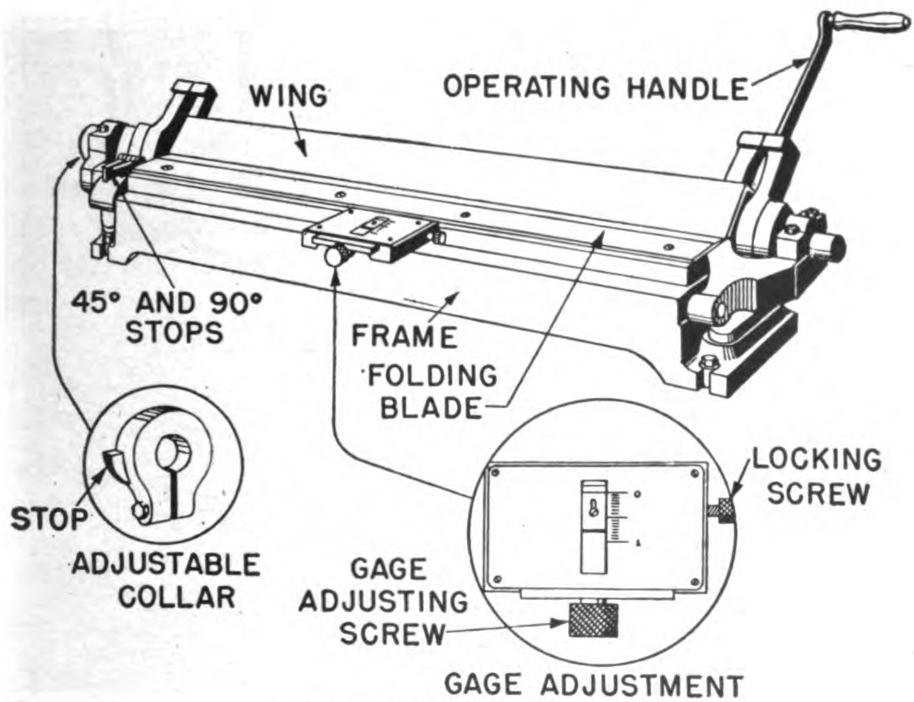


Figure 14.—A bar folder.

One big advantage of the bar folder (figure 14) is that it has a DEPTH GAGE which controls the amount of metal slipped under the BLADE (the forming edge). After you set the depth gage, the wing adjustment, and the clamping pressure adjustment, you can make any number of duplicate folds.

The WING is set close to the edge of the blade for a sharp bend and farther away for a radius bend. The width of the gap between the wing and the blade determines the radius of the bend.

Automatic STOPS are provided for making bends of 90 degrees and 45 degrees. A special, adjustable stop is also provided, and it may be set to stop the bend at other angles. Don't forget to allow for springback. The 45 and 90 degree stops automatically allow for average spring-

back. After you set up the adjustments of the folder, check its operation with a piece of scrap stock of the same material and thickness as the stock you're going to fold.

The bar folder is faster and more accurate than the brake for making hems, seams, and locks. Figure 15 shows you how a hem is folded.

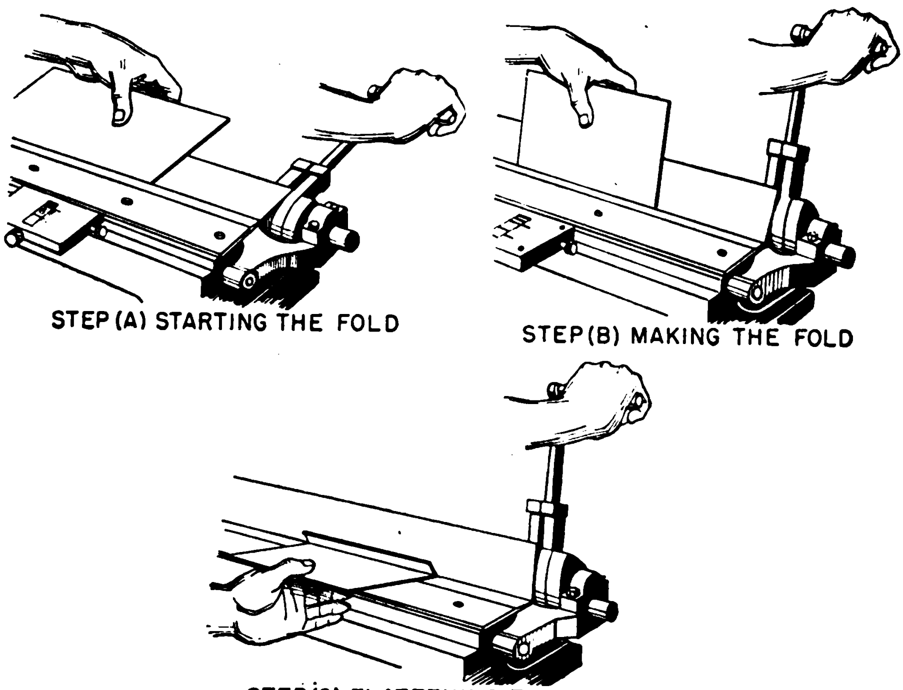


Figure 15.—Folding a hem.

Don't abuse the bar folder. It has a rugged appearance but is easily damaged if the capacity is exceeded or if the machine is not adjusted properly. And don't try to form wire, rod, or bars—you'll nick the folding blade and spring the wing.

SLIP-ROLL FORMING MACHINE

Cylinders and conical shapes may be made on the SLIP-ROLL FORMER (figure 16). This machine has three rolls. When the crank is turned, the two front rolls grip the sheet and feed it through the machine. The third roll, at the back, is an idler which forms the sheet. The lower front roll is adjusted vertically at both ends to CONTROL THE PRESSURE. The back roll is adjusted to REGULATE THE RADIUS of the bend. The top front roll (the slip-roll) may be released and raised at one end to allow the formed piece to be removed.

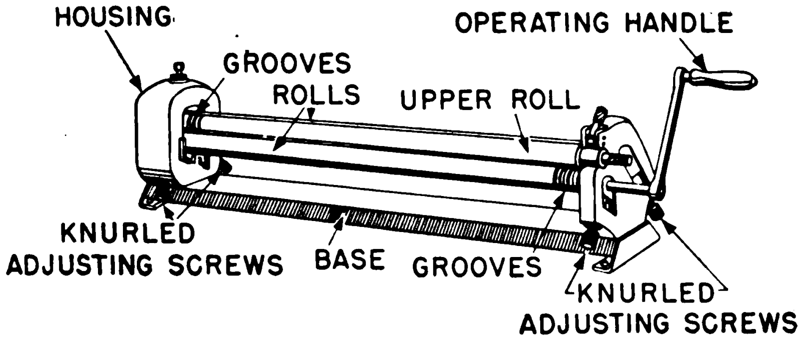


Figure 16.—Slip-roll forming machine.

When forming cylinders, all three rolls must be PARALLEL. Start a sheet as shown in figure 17*A*. As soon as the front rolls grip the sheet, pull the sheet up to get the effect shown in *B*. Then roll the piece on through (figure 17*C*). You'll soon learn to set the back roll to get the desired curve. Experience is the best teacher for this operation.

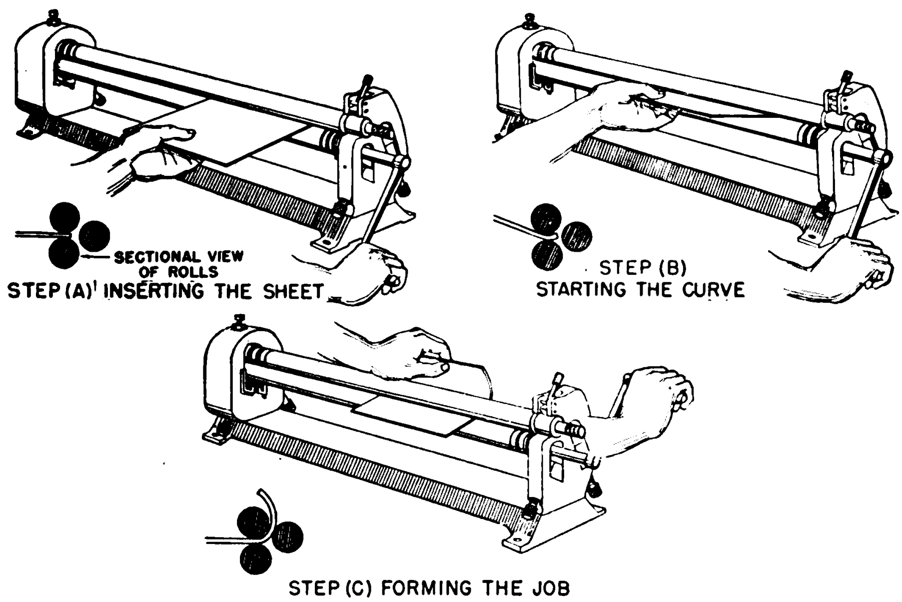


Figure 17.—Forming a cylinder.

If you need to form a conical shape, you can do it by setting the back roll at an angle to the front rolls. See figure 18*A*. SLIDE the piece of metal in order to keep the radial lines (*AA′*, *BB′*, and *CC′*) lined up with the rolls or you won't get the right shape.

The GROOVES in the rolls allow a wire or wired edge to be formed, as in figure 18*B*. Make sure you start a wired edge in the groove so that the wire will be on the side you want it on.

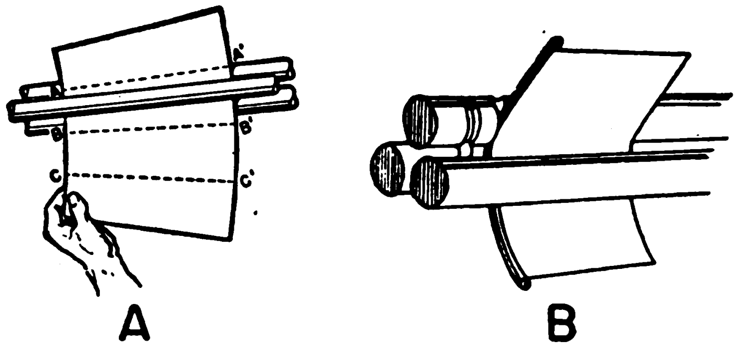


Figure 18.—Rolling a conical shape; rolling a wired edge.

Keep the rolls clean and lubricate the bearings and gears regularly. Then the machine will operate smoothly.

ROTARY MACHINES

You can't use a bar folder to form curved edges—that's where ROTARY MACHINES take over. Rotary machines are also used on straight edges for some operations.

If you're working in a large shop you'll have individual rotary machines for BURRING, TURNING, WIRING, BEADING,

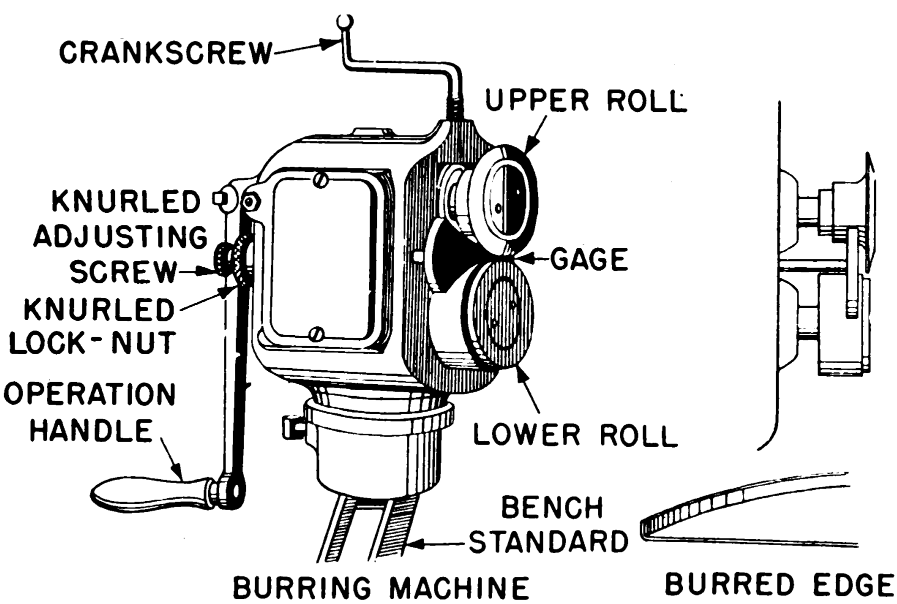


Figure 19.—Rotary machine with burring rolls.

SETTING DOWN, GROOVING, and CRIMPING. Smaller shops will have fewer machines. Some of them will be of the COMBINATION variety with one head and several sets of rolls. A combination ROTARY HEAD, with burring rolls mounted, is pictured in figure 19. This rotary head will take sets of rolls for burring, turning, wiring, and elbow

edging. The rolls are secured to the shafts by round nuts which screw flush with the outside of the rolls. Don't be surprised if some of these nuts have left-hand threads. A special face-pin spanner wrench is used on these nuts.

The BURRING ROLLS are used to turn an edge at right angles to form burrs (narrow flanges) for seams or hems. Ordinarily, you'll have two sets of burring rolls—one set for narrow burrs and one for wide burrs. A typical use is for burring the disks which form the bottoms of some buckets and tanks.

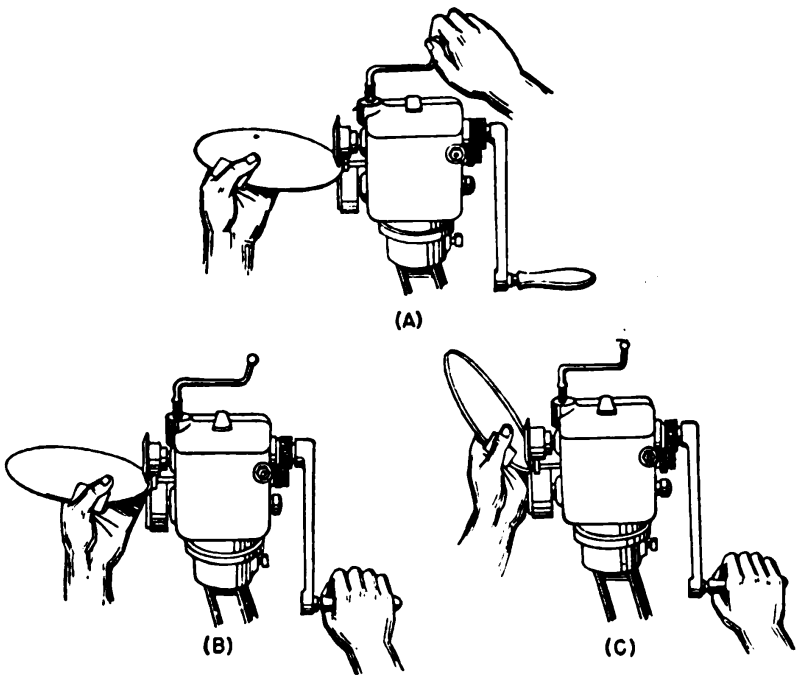


Figure 20.—Burring a disk.

It takes a little patience and some practice to turn out a perfect burr—like the one the workman in figure 20 is cranking out. Here's how you do it—

First, adjust and aline the rolls so that the inside edge of the top roll fits over the shoulder of the bottom roll. Make the CLEARANCE equal to the thickness of the metal. This is important—less clearance will cause the top roll to act as a shear and damage your stock.

Next, set the gage to turn up the proper amount of metal. This is usually from 1/8 inch to 3/16 inch.

Then, place the disk as shown in figure 20*A* and move the top roll down until it grips the stock and creases it slightly.

Now, crank the handle. Keep the edge of the disk tight against the gage. Allow the disk to revolve as you crank.

The first revolution should be fairly slow so you can get the burr accurately established. After the first revolution of the disk, disregard the gage and follow the crease.

After the first round, increase the top roll pressure and turn as before. Raise the disk slightly after each revolution. After the first round you can crank faster and faster—especially after you've burred several disks and have begun to get the hang of it.

The TURNING ROLLS are used to form rounded flanges—similar to burred edges but having radii. These rolls are used to form edges for wiring. Several sets of rolls like those in figure 21 are usually provided.

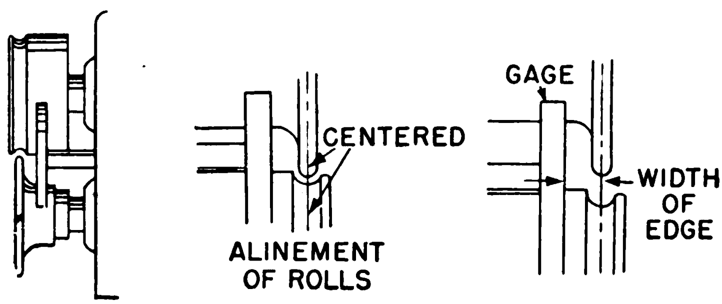


Figure 21.—Turning rolls.

The turning machine does a good job if you keep the rolls alined, set the gage properly, and hold the edge of your metal firmly against the gage during the first revolution.

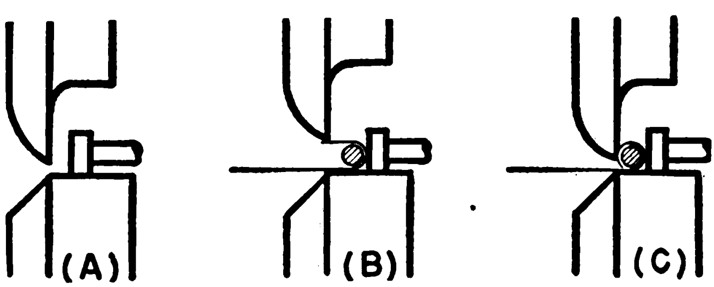


Figure 22.—Wiring an edge.

ELBOW EDGING ROLLS are similar to turning rolls but have V-grooves in the lower rolls and matching upper rolls.

WIRING ROLLS are used to form or shape the metal

around a wire. The edge of the metal is first turned on the bar folder or rotary turning rolls. The job is completed with the wiring rolls. Parts *B* and *C* of figure 22 show these two steps. Wiring rolls may be used on either straight or curved edges.

SETTING-DOWN MACHINES are used to close single seams. They are separate, one-job machines. Their beveled jaws grip the seam and mash it down to make it tight and smooth.

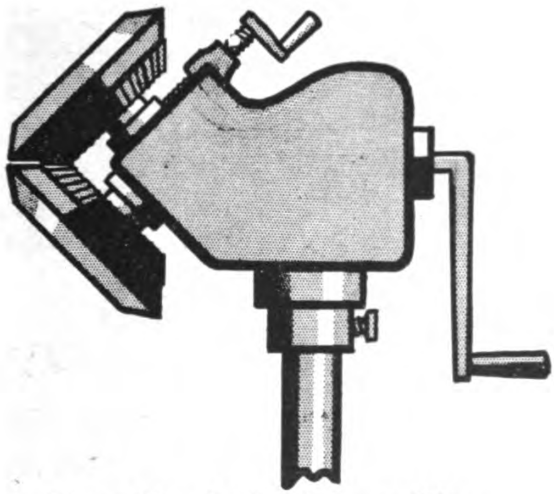


Figure 23.—Setting-down machine.

BEADING may be done, in an emergency, with the turning rolls of a combination rotary machine. The DEEP-THROAT BEADING MACHINE, however, is especially designed

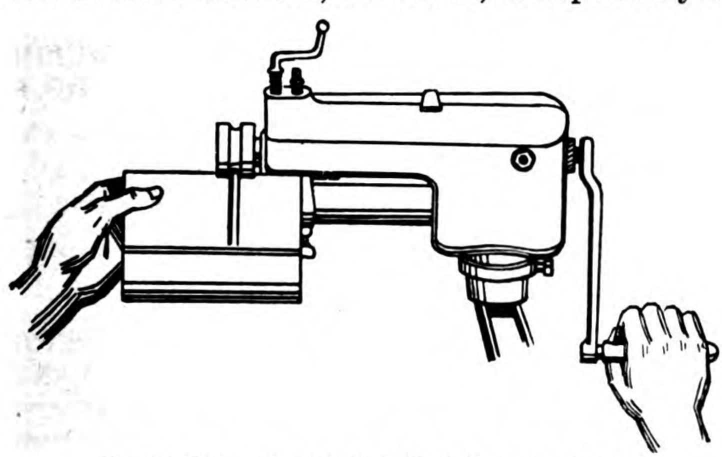


Figure 24.—Deep-throat beading machine.

for beading. One is shown in figure 24. Several types of beading rolls may be used with this machine.

Take several revolutions to form a bead, thus avoiding severe stresses and possible cracks. Start beading next to

the seam and stop just before the seam is reached. NEVER ALLOW A SEAM TO PASS THROUGH THE ROLLS. If the thick seam goes through the rolls, it will spring the machine and weaken the seam.

FLANGING MACHINES are used to do the same job as burring machines—but they handle heavier gage material

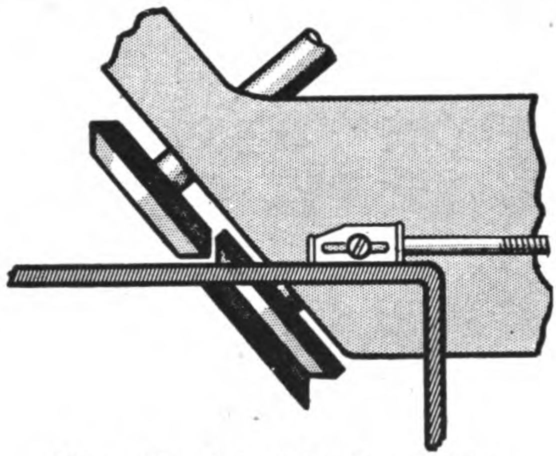


Figure 25.—Rotary flanging machine.

and can be used to make wider flanges. The rolls, table, and gage of a flanging machine are shown in figure 25.

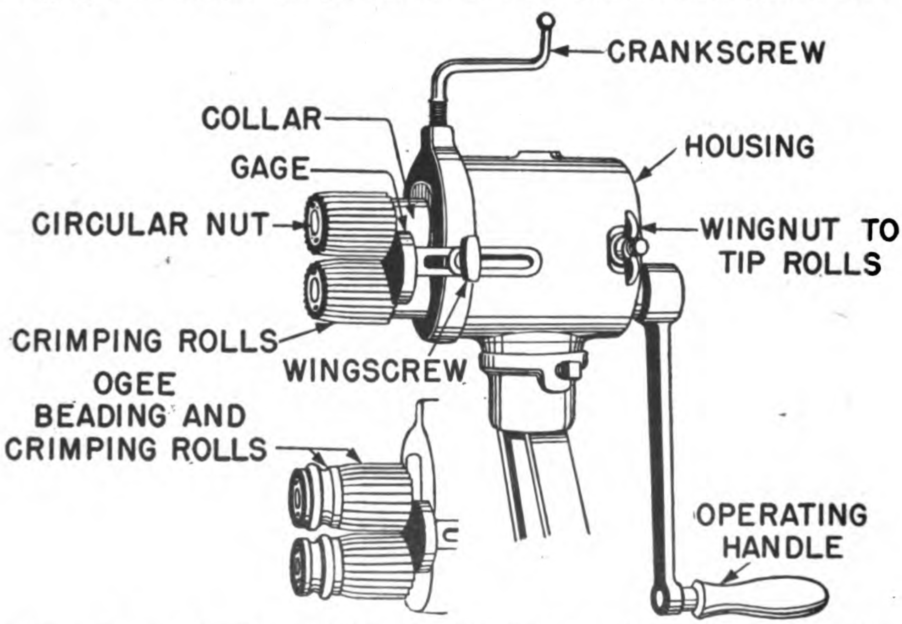


Figure 26.—Crimping machine; combination crimping and beading rolls.

CRIMPING MACHINES (figure 26) are used to shrink (by corrugation) the ends of metal cylinders so they can be fitted into other cylinders of the same diameter. Some crimping machines also carry beading rolls next to the

crimping rolls, as in the lower drawing of figure 26. The bead reinforces the cylinder and prevents it from slipping too far into the other cylinder.

For jobs with riveted or grooved seams, start the crimp near the seam and run it around until it just comes back to the seam. NEVER crimp over a seam—it will damage the rolls and spring the shafts. Keep the edge of the cylinder against the gage and you'll get a neat job.

CHECK AND DOUBLE-CHECK

You'll get a good job of folding, roll-forming, burring, turning, wiring, beading, or crimping if you CHECK YOUR MACHINE SET-UP thoroughly and PROCEED CAREFULLY.

Always double-check your machine set-up by doing a practice job on a piece of scrap stock of the same material and thickness that you are using for the job. This will

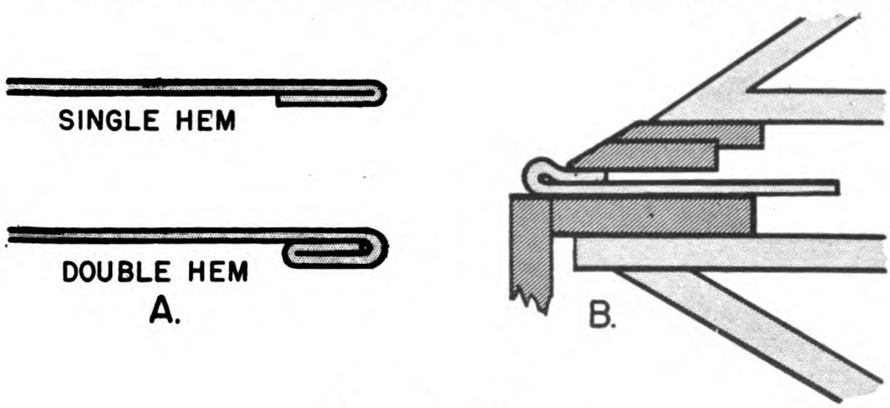


Figure 27.—Hems.

save you a lot of time and trouble and save Uncle Sam a lot of sheet metal.

Take it easy when you form galvanized sheets. If you're too rough with this material, the zinc coating will flake and chip off, leaving the bare base metal an easy mark for corrosion.

Keep rotary machines, brakes, bar folders, shears, and other machines clean and lubricated. Avoid using any machine in any way that will cause working surfaces to acquire scratches, dents, and nicks. Wipe all unpainted surfaces with an oily rag occasionally and you won't have much trouble with rust.

EDGE STIFFENERS

The exposed edges of sheet metal parts are formed and

shaped to eliminate raw edges and to strengthen and reinforce the structure. One form of edge stiffener is the HEM, illustrated in figure 27.

SINGLE HEMS can be made with either the bar folder or the brake. When you're working with curved edges, the hems may be started with the burring rolls and finished by hand over a stake. For straight hems on light metal, the bar folder is your best bet. Just adjust the folder, stick the metal under the blade, and pull the wing as far as it will go. Then remove the metal, place the fold under the wing, and close the wing against the blade.

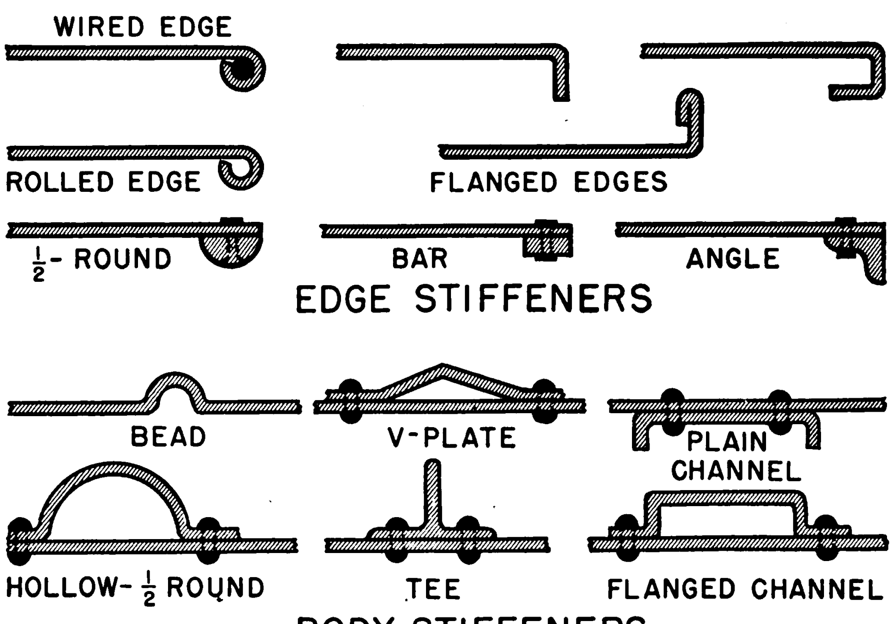


Figure 28.—Stiffeners.

If you form hems on a brake, close the hems so they will look like part *B* of figure 27. This hem is stronger than a plain hem because of the curve and because the metal is not overstretched at the fold. You can make this hem easily if you use the brake as shown.

A DOUBLE HEM is made by simply folding over a single hem. This double hem is much stronger than a single hem and it's completely smooth—no sharp or ragged edges are exposed.

Figure 28 shows a number of other edge stiffeners along with some body stiffeners.

WIRED EDGES are often used to form the edges of trays, air supply terminals, buckets, cans, and funnels. These

edges are made by wrapping the metal edge around a wire. See figure 29. For thin metal, the ALLOWANCE for a wire edge is 2½ times the diameter of the wire. It is slightly more for heavy gages. These edges are strong and smooth when properly made. The metal should always fit tightly around and cover the wire completely. The wired edges may be finished with the wiring rolls.

A SETTING HAMMER may be used to smooth and finish a wired edge if no wiring machine is available.

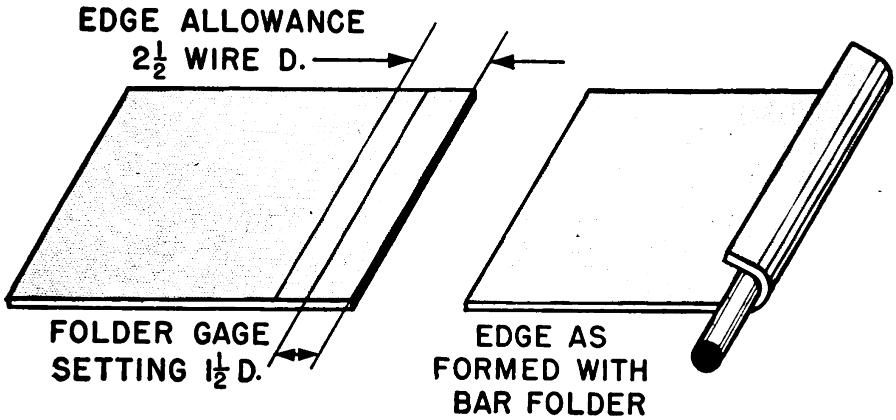


Figure 29.—Planning and folding for a wired edge.

An edge for wiring may be TURNED with the turning rolls, the brake, or the bar folder. You can wire the edge of a cylinder BEFORE the cylinder is rolled to shape. After

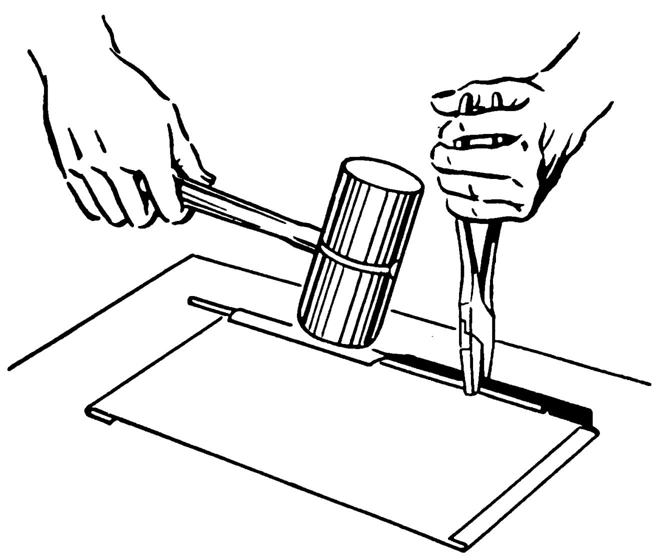


Figure 30.—Wiring a straight edge before forming.

the edge is turned, it is formed around the wire as shown in figure 30. The pliers are used to hold the wire tight against the metal and to protect your fingers.

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When you are wiring the edge of a rectangular box or tray you can form the wire in a vise (figure 31) and form the turned edge over the wire with a mallet or with the wiring rolls.

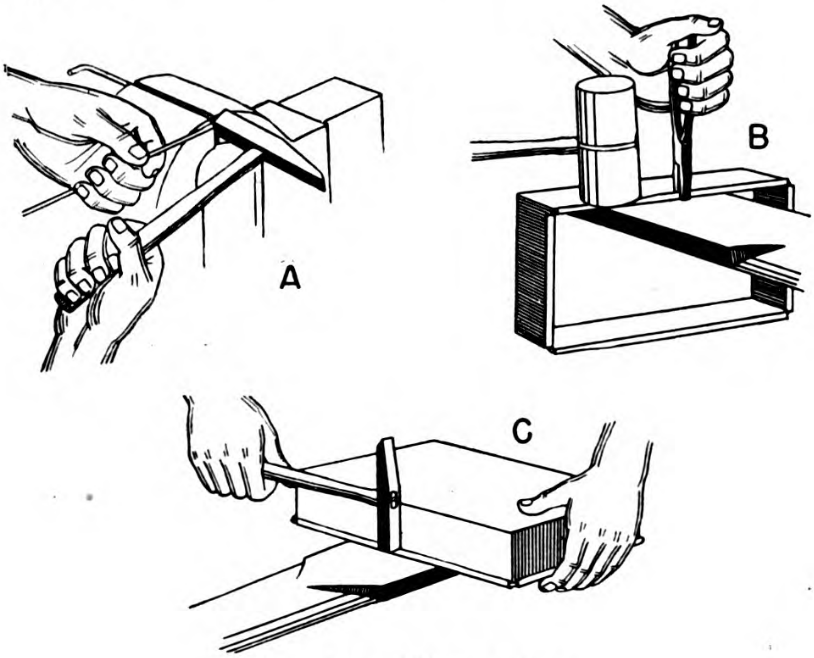

Figure 31.—Wiring a box.

SEAMS AND LOCKS

Sheet metal parts are often fastened with seams and locks. Some of these seams and locks are self-sufficient and require no other fastening. Others are held with rivets, bolts, sheet metal screws, or solder. Waterproof seams are seamed or riveted and then soldered.

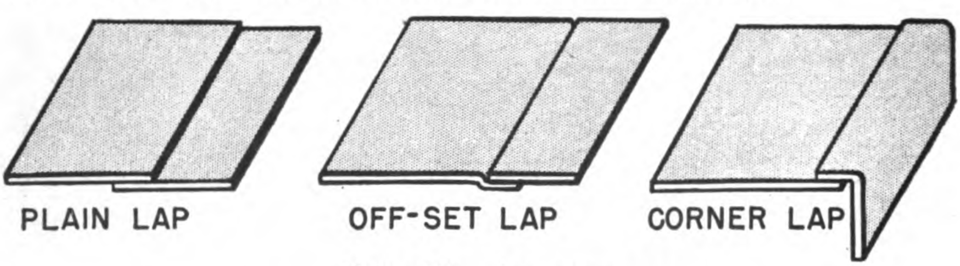

Figure 32.—Lap seams.

Seams and locks must be PLANNED so that the proper allowance (lap or tab) is left on the metal to form the seam. The allowance depends largely on the type of seam and its width.

LAP SEAMS

Three types of simple lap seams are shown in figure 32.

These seams are soldered, brazed, riveted, bolted, or fastened with screws. Soldered seams should be sweated together. If you've forgotten how to sweat solder, read Chapter 9 in your *Use of Tools* book.

Riveted lap seams are much stronger than soldered lap seams. Flat head tinners' rivets are usually used. They are drawn upset and headed as shown in figure 33. Seams that must be both strong and watertight are both riveted and soldered.

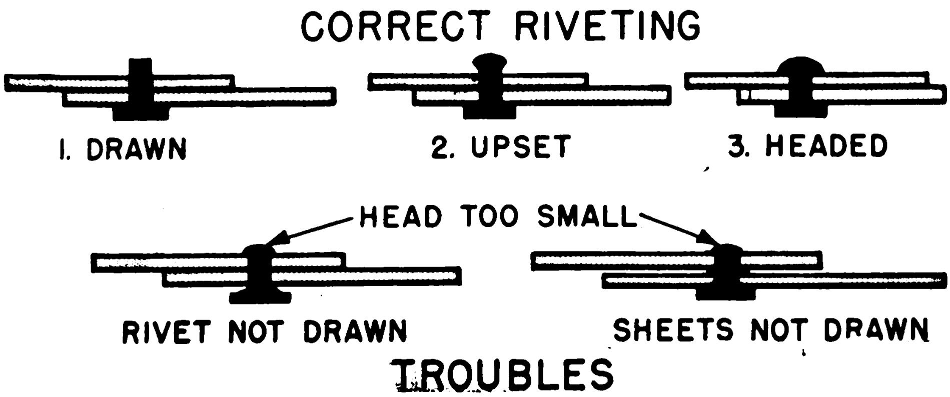

Figure 33.—Riveted lap seam.

GROOVED LOCK SEAMS

If you cut through the body seam of an ordinary tin can you'll probably find that the manufacturer used a grooved seam. This type of seam is used to join the opposite edges of a sheet to form buckets, air ducts, pipes and funnels.

The first step in making the grooved seam is to fold OPEN HEMS on the two opposite edges. As shown in the

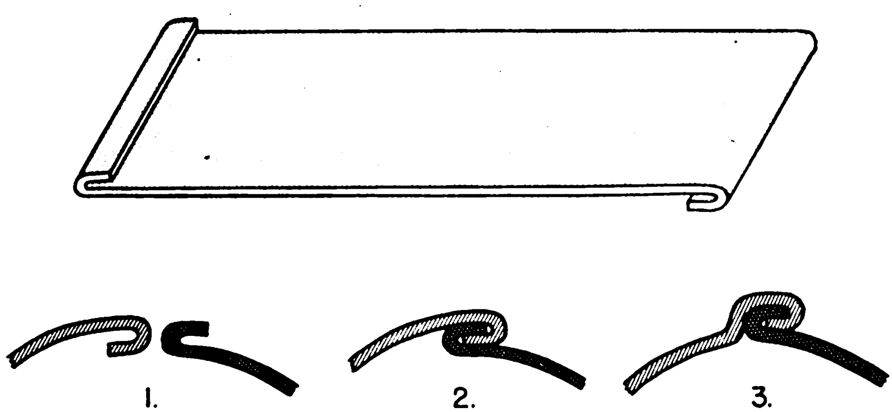

Figure 34.—The grooved seam.

upper drawing of figure 34, one hem is made on one side of the sheet, the other on the opposite side. These open hems are then hooked together and flattened snugly with a mal-

let. Then the seam is placed over a stake or bar and grooved with the HAND GROOVER. The lower part of figure 34 shows these steps. Large shops may have special grooving bars and machines. The seam is soldered if it must be air or water tight.

Extra metal must be allowed for making the seam. An allowance of 2½ to 3 times the seam width is about right (2 in figure 34).

DOUBLE SEAMS

PLAIN DOUBLE SEAMS are the kind often used on the bottoms of cylindrical containers—buckets, cans, trays, and boxes. These seams are also used in the construction of air ducts. Figure 35 shows a double seam in four stages

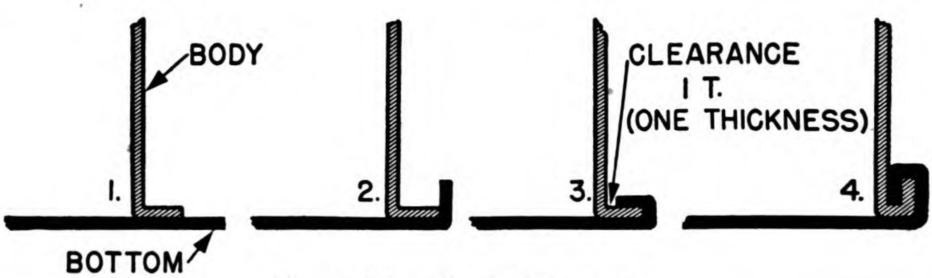

Figure 35.—The double seam.

of construction. The CLEARANCE indicated by the arrow in step three is important. It should be slightly greater than the metal thickness. If you don't have enough clearance the seam will be forced apart and the wall of the object forced out of shape.

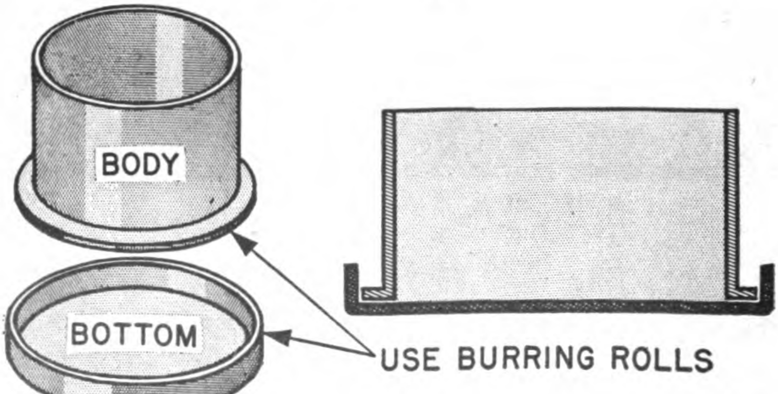

Figure 36.—Preparation for double seam.

Burred disks, known as SNAP BOTTOMS, are used for the bottoms of cylindrical and conical containers. The

necessary machine preparation for a disk and cylinder is shown in figure 36.

After the cylinder and bottom are snapped together, the burred edge of the bottom is turned over the burred edge of the cylinder (figure 37*A*) and "set down" with the setting-down machine (*B*). After the seam is smoothed and flattened, it may be partially closed by turn-

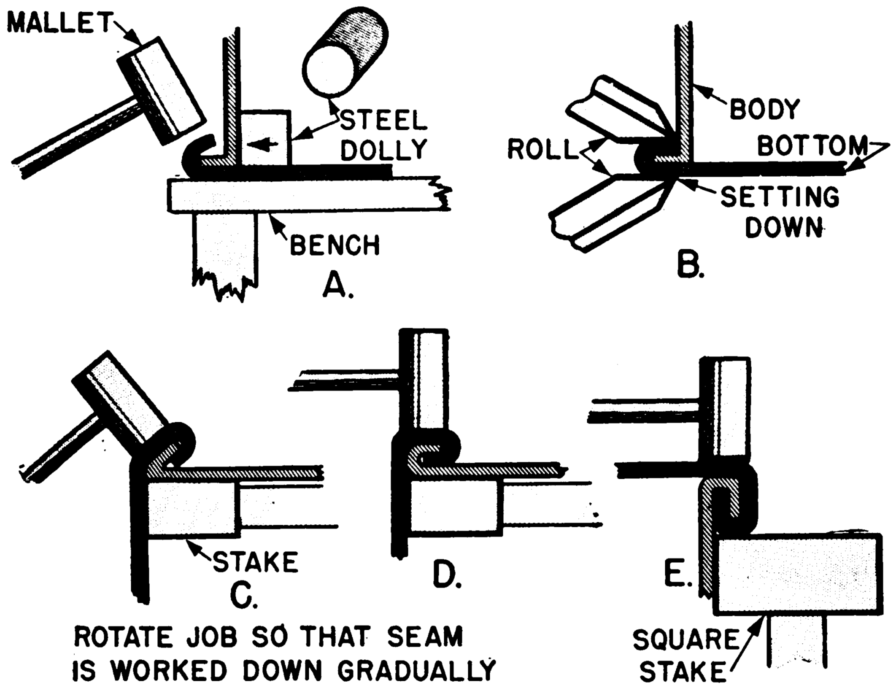

Figure 37.—Finishing the double seam of a cylinder bottom.

ing it upward toward the top of the cylinder as you continue to run the seam through the rolls. The next step is to place the cylinder over a stake (*C*) and to finish pounding the seam over with a mallet (*D* and *E*). The seam is then smoothed and straightened as shown.

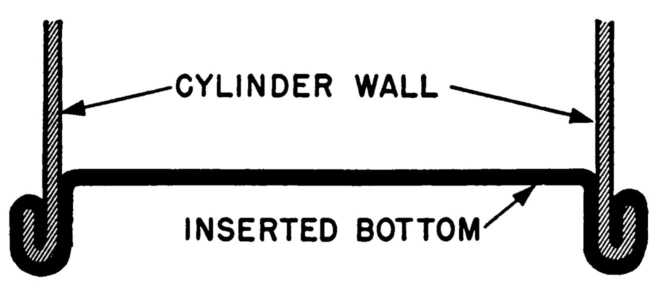

Figure 38.—Insert double seam.

The INSERT DOUBLE SEAM (figure 38) is used instead of the plain seam on some jobs. You can see why it's better

for containers such as buckets and tanks. One big advantage of this seam is that it can be used on long cylinders. The seam can be formed from the outside by putting only the end of the cylinder over the stake.

SINGLE SEAMS are similar to double seams except that the single seams are not closed. When two sheets are singled-seamed so that they are in line—in the same plane—the seam is known as a STANDING SEAM. Figure 39 shows a single seam and two types of standing seams. Standing seams are commonly used to join the sections of sheet metal roofs.

Figure 39.—Single seam and standing seams.

CORNER SEAMS AND LOCKS

The ordinary double seam is one of the best corner locks but it can't be used for all jobs. Other locks and seams have been developed for special uses.

The PITTSBURGH LOCK is a tin-bender's favorite. It may be made in the shop and assembled on the job with only a mallet. On many jobs that's a big advantage. You'll find this seam used on air ducts and for locker construction. A Pittsburgh lock is shown at the top of figure 40. Notice that one edge is merely flanged. The other edge may be formed on the cornice brake as shown. In step 4 a scrap piece (not shown in the illustration) may be inserted to keep the seam open. Don't attempt to make a Pittsburgh lock unless you have a brake.

POCKET SEAMS, two of which are shown in figure 41, are easily made and assembled. Pocket seams are not self-locking—they are usually riveted and then soldered.

The INSIDE CUP SEAM, also shown in figure 41, is similar to the Pittsburgh lock. It's used ordinarily on ducts which are large enough to permit working on the inside.

FLANGED JOINTS also are used in corners. Two types are illustrated in figure 41. Fastenings must be used if

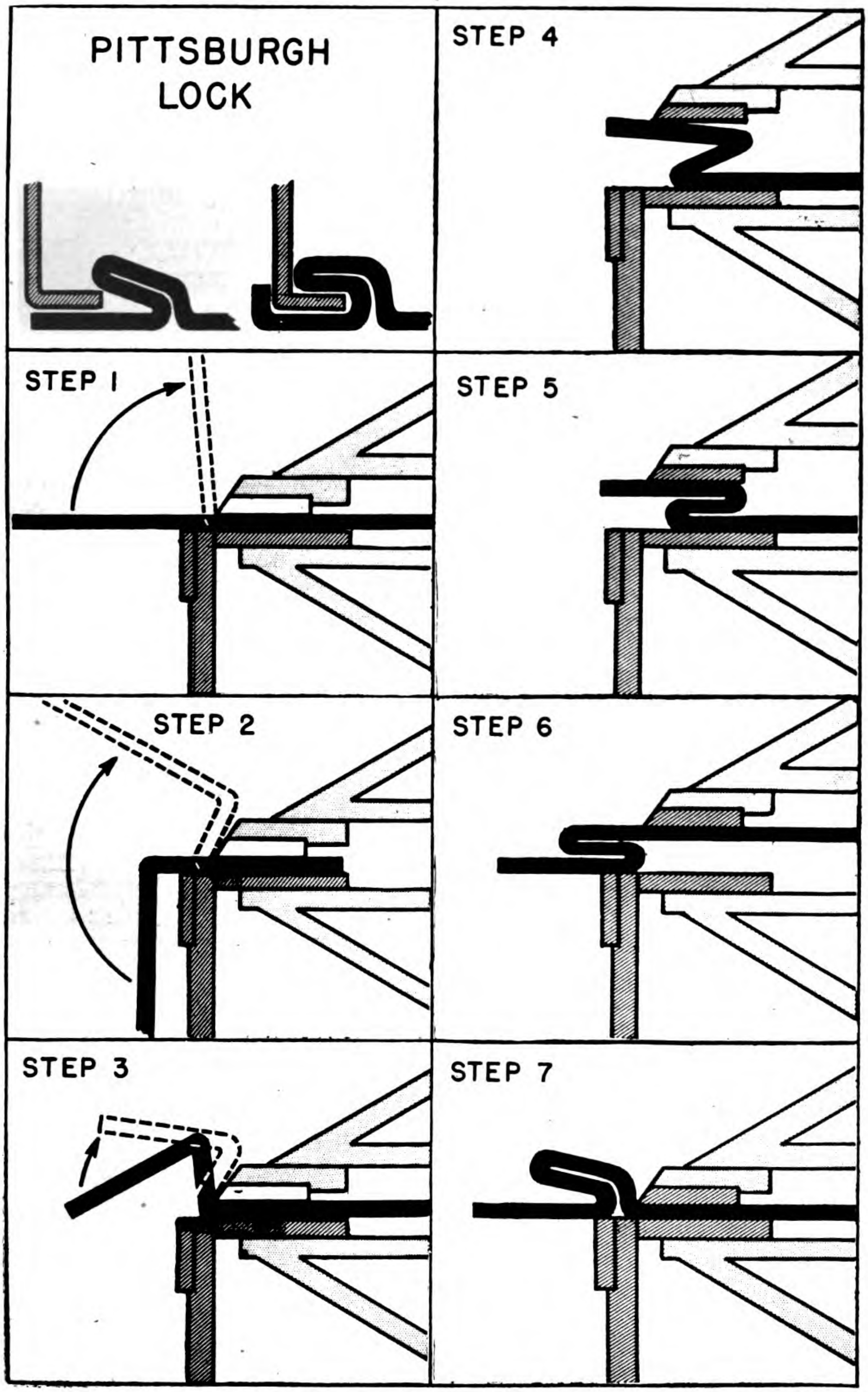

Figure 40.—The Pittsburgh lock seam.

you want the flanged joints to be strong. It's almost impossible to make these joints permanently watertight.

ASSORTED SEAMS AND JOINTS

An assortment of other sheet-metal seams and joints

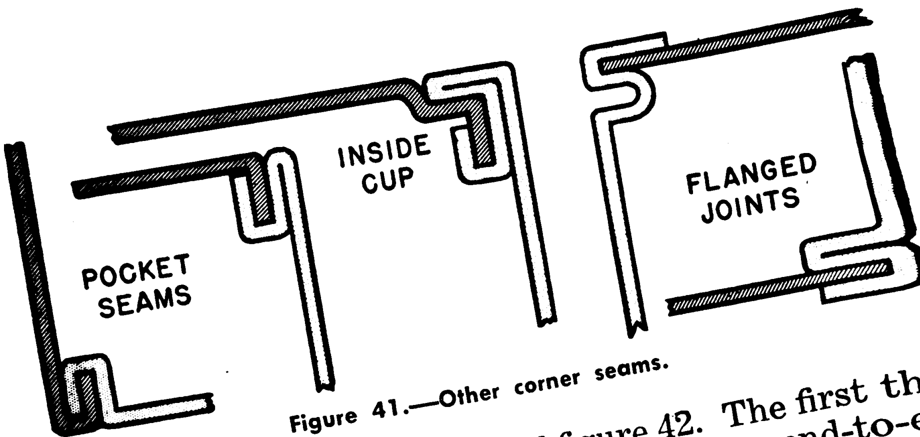

Figure 41.—Other corner seams.

is shown in the sectional view of figure 42. The first three (top) are used when joining round sections end-to-end. The SLIP CAPS and DRIVE LOCKS are used on ducts and roofs. As roofing material is usually thin, ductile terne plate, the seams are easy to form.

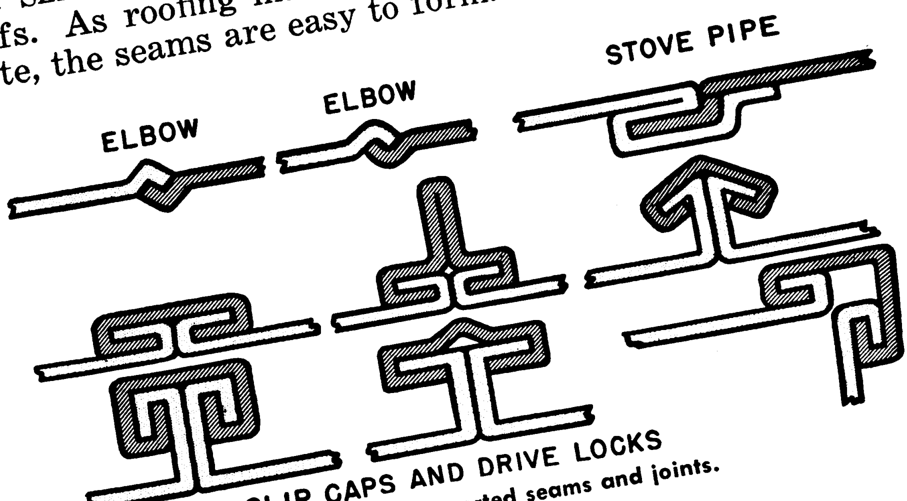

Figure 42.—Assorted seams and joints.

PRACTICAL PROJECTS

Test your ability to make sheet metal seams and locks by making up the practice job shown in figure 43*A*. Use 2-inch strips of scrap galvanized steel, 18 to 20 gage. Determine the proper allowances for each seam before you start to work. Your practice job won't be right unless the finished job is of the PRESCRIBED size.

After you have finished this practice piece, make up the jobs shown in figures 43*B*, 43*C* and 43*D*. These drawings are taken from the basic Training Course, *Use of Blueprints*, and if you need some help in making the layouts you can refer to Chapter 8 of the Blueprints book and the Quiz for that chapter.

Make the plain box (figure 43*B*) 2″ high, 3″ wide, and 6″ long, with ½″ tabs. The tabs are indicated by "T" in the illustration.

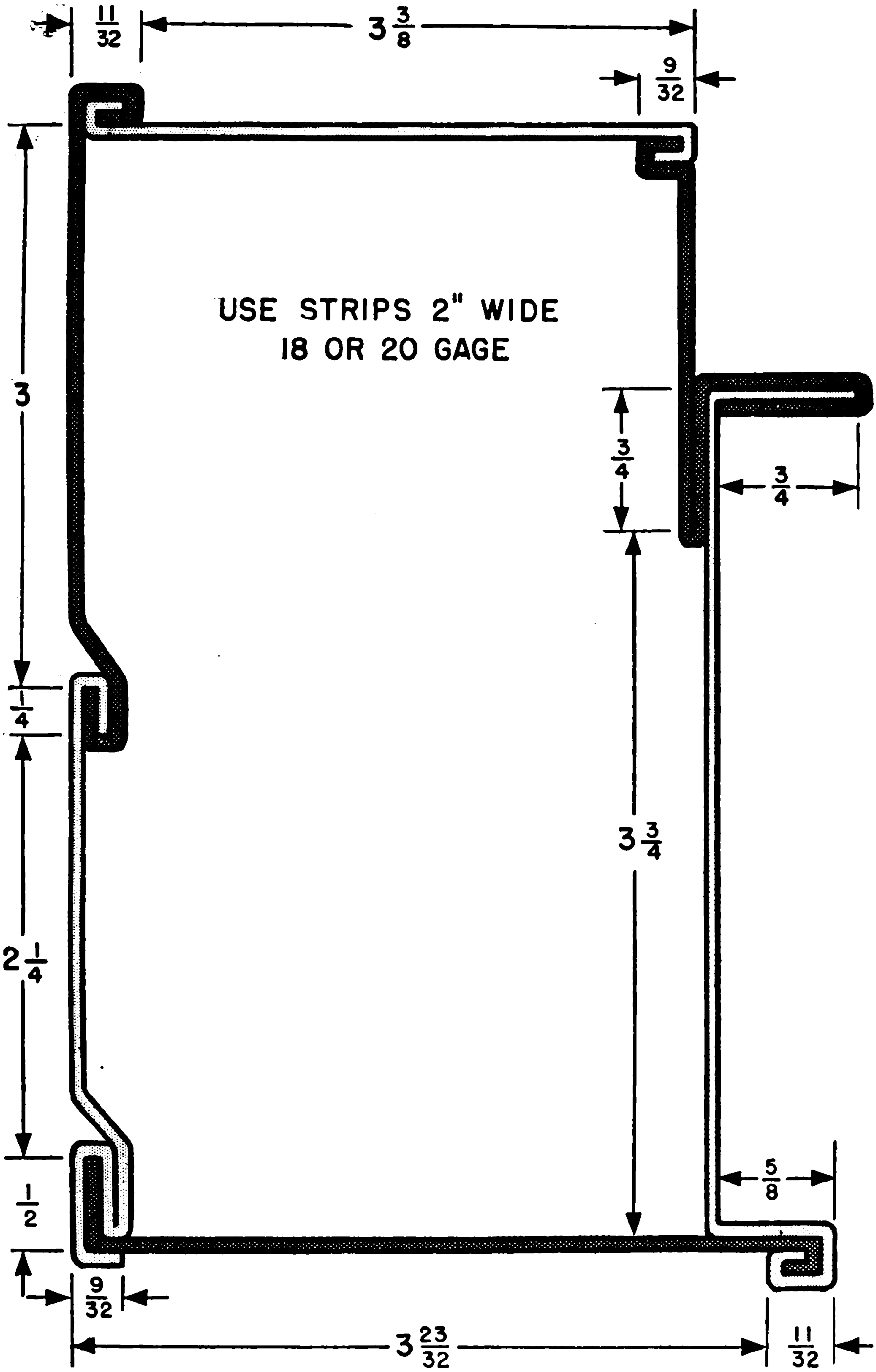

Figure 43A.—Practice seaming exercise.

For the flared-end box (figure 43*C*), use the dimensions shown, plan the proper allowance, and put a wired edge on the box.

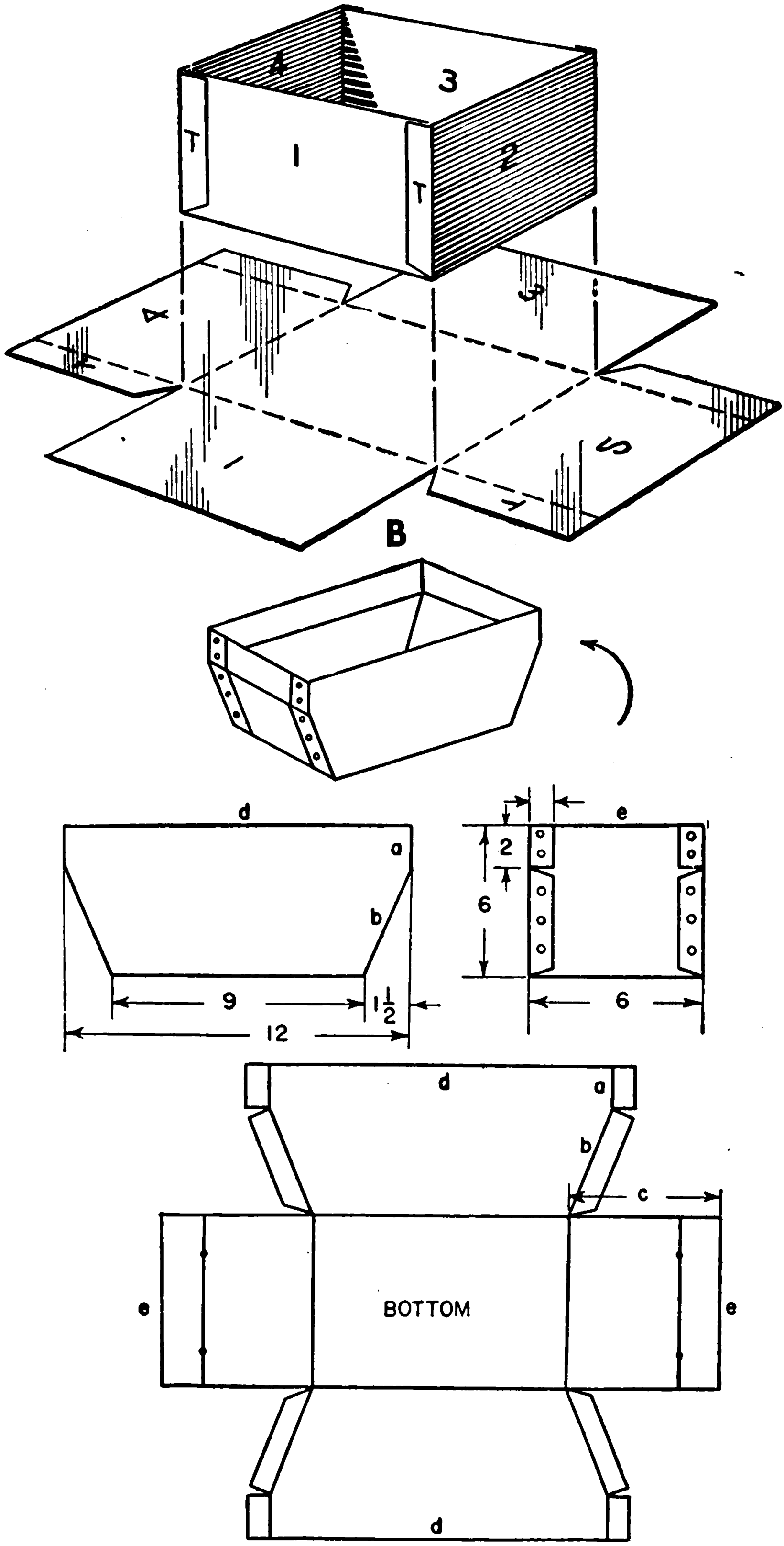

Figure 43B.—Plain Box; C.—Flared-end box.

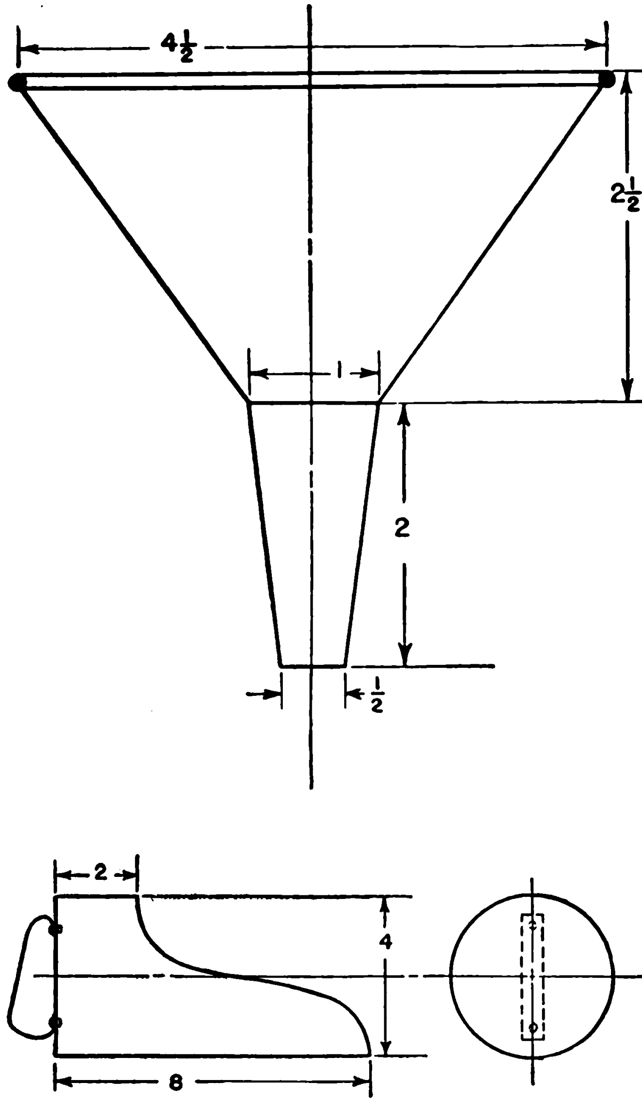

Figure 43*D*.—Funnel and powder scoop.

In making the body and spout of the funnel at the top of figure 43*D*, allow $5/16''$ to cover the wire around the top. For the seam allowance, add $3/16''$ to one edge and $7/16''$ to the other edge. The powder scoop at the bottom of figure 43*D* requires the same seam allowance as the funnel.

CHAPTER 3

GAS-WELDING EQUIPMENT

EQUIPMENT SET-UP

Gas-welding, oxyacetylene welding, ox-welding—take your choice. They all mean about the same thing—using a controlled flame of acetylene gas to melt the edges or surfaces of two pieces of metal so that the molten parts flow together to form a single, solid piece.

Because the acetylene does not burn satisfactorily in air or compressed air, PURE OXYGEN is mixed with the acetylene to increase its combustibility. The oxygen used is about 99.5 percent pure—so pure that it can be used with pulmotors, oxygen tents, and rescue-breathing equipment.

On shore stations you may have occasion to use HYDROGEN gas instead of acetylene. As hydrogen does not produce as hot a flame as acetylene, it is not generally used aboard ship for ordinary welding. But—when it comes to underwater cutting, hydrogen is preferred because it will not explode under water pressure. Acetylene sometimes does.

Both oxygen and acetylene are contained in strong cylinders or tanks called BOTTLES. A VALVE at the top of a bottle allows the gas to be piped to a REGULATOR. Two

GAGES are attached to each regulator—one to indicate BOTTLE PRESSURE, the other to indicate the WORKING PRESSURE on the hose.

Acetylene is conveyed from its regulator to the torch through a RED hose. Oxygen hoses are GREEN. The two gases meet in a MIXING HEAD inside the torch. This mixing head combines the gases and feeds the mixture through a small ORIFICE (hole) in the torch TIP.

The complete outfit, set up ready to use, is shown in figure 44.

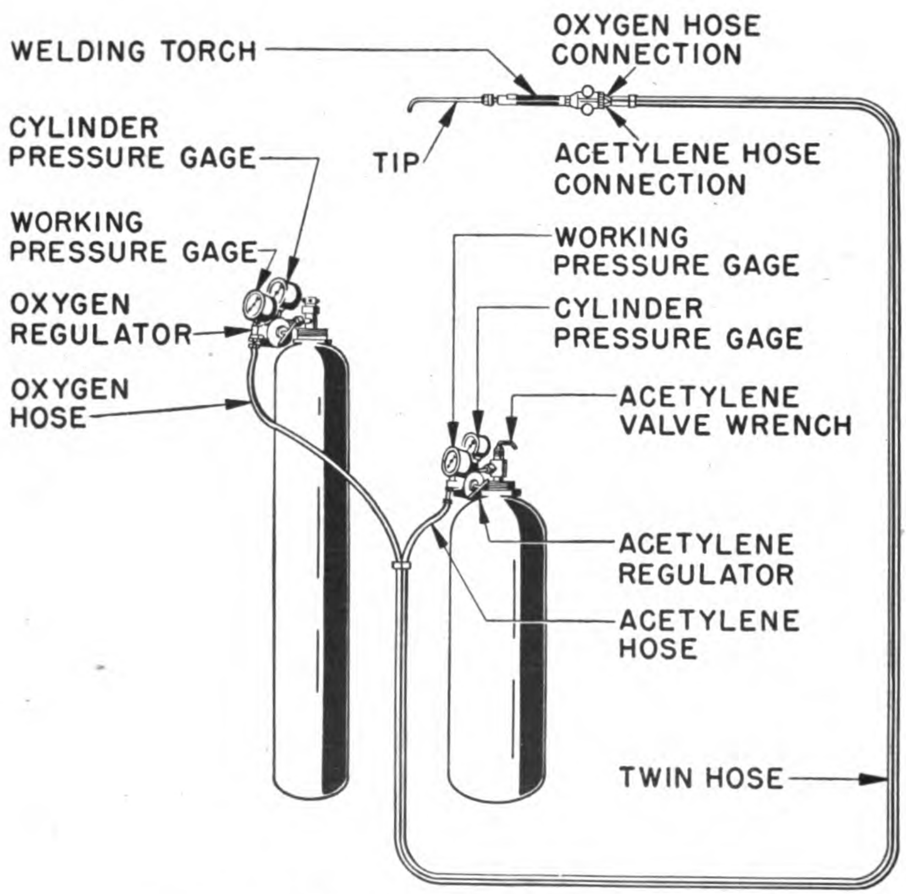

Figure 44.—Equipment set-up for gas welding.

The SAFE handling of this equipment is discussed in this chapter in detail, along with instructions for its assembly and disassembly. ACETYLENE AND OXYGEN ARE BOTH EXTREMELY DANGEROUS WHEN IMPROPERLY HANDLED. Just as a Gunner's Mate must be an expert in handling explosives, YOU must be an expert in handling welding gases.

OXYGEN BOTTLES

Oxygen is usually made by a process known technically as "fractional distillation of liquid air." The bottles (cylinders) in which oxygen is stored are of extra strong construction. They have to be, in order to withstand the 2,000 pounds per square inch pressure under which the oxygen is placed in the bottles.

A typical oxygen bottle is about 50 inches long and about 9 inches in diameter. At 70°F., it it holds about 220 cubic feet of oxygen at 2,000 psi. A smaller size contains about 110 cubic feet at the same temperature and pressure. As the smaller bottle is easy to move around, it's used for emergency welding and cutting.

When the temperature goes up, the oxygen pressure goes up. Therefore, stow oxygen bottles in cool places. At 0°F., a full tank has a pressure of only 1,630 psi. At 120°F., the pressure increases to more than 2,200 psi. You don't have to worry about the low temperatures—WATCH OUT FOR THE HIGH ONES.

Dented or corroded bottles should not be brought aboard ship. Keep oil and grease away from oxygen. When oil, grease and oxygen get together, you may have a fire on your hands—a fire that's difficult to control.

Oxygen bottles are painted black with a six-inch neck band (stripe) of DARK GREEN. A white vertical stripe on an oxygen bottle indicates that the bottle is of shatterproof construction. The valve end of the bottle has a black cap which screws to the neck ring of the bottle.

A FUSIBLE PLUG—one that melts at 220°F.—is built into the cylinder valve. This plug melts in case of fire or other excessive heat, thus preventing explosions.

Oxygen bottles should be stored vertically, with the valve ends up. Always store oxygen and acetylene bottles in DIFFERENT places. Never store oxygen bottles near steam pipes or heaters. Avoid dropping, bumping, or rolling them.

Remember those stowage precautions and observe the following additional rules and you won't have any trouble with oxygen—

DO NOT ALLOW OXYGEN TO COME IN CONTACT WITH OIL AND GREASE. If you do, an instantaneous explosion may result. Do not handle bottles, valves, hose, or torch with oily or greasy hands, or with greasy gloves.

DO NOT OIL VALVES OR FITTINGS. Oiling is dangerous and is not required.

DO NOT USE OXYGEN AS A SUBSTITUTE FOR COMPRESSED AIR TO BLOW OUT LINES, OPERATE PNEUMATIC EQUIPMENT, OR DUST OFF YOUR CLOTHING. Use oxygen ONLY to operate the welding and cutting torches. Close the oxygen bottle valve when you're through using the torch.

Other IMPORTANT SAFETY RULES are listed at the back of this chapter. LEARN THEM. The oxygen-acetylene equipment is probably the most dangerous that a Metalsmith is called on to use. Your life, and the lives of others, may depend on your knowledge of safety rules.

ACETYLENE BOTTLES

Acetylene, the fuel for the flame, is a colorless gas which has its own peculiar odor. When it's mixed with air or oxygen, it forms an EXTREMELY EXPLOSIVE MIXTURE. A spark will cause instantaneous combustion throughout the mixture. Air containing as little as 3 percent acetylene forms an explosive mixture.

To make matters worse, acetylene is SELF-EXPLOSIVE if it is kept in the pure state, under a pressure over 15 psi. And yet, it can be shipped, stored, and used with safety. Here's why—

Acetylene bottles are specially constructed. They are filled with a porous material—the pithy centers of cornstalks, balsa wood, and soft asbestos fibers. ACETONE, a liquid chemical which can absorb a lot of acetylene, is then placed in the bottle. The acetone content is about 40 percent of the volume. Acetone soaks up about 240 TIMES its own volume of acetylene at 250 psi. When absorbed by the acetone, the acetylene is safe if kept at a pressure of 250 psi.

An acetylene bottle is painted black, with a six-inch BLUE band at the top. Below the blue band is a three-inch RED band. The protective cap is BLACK ordinarily. The acetylene hose leading from the regulator to the torch is RED.

Bottles of acetylene should always be stored ON END, with the valve UP. This prevents the acetone from entering the valve, regulator, hose, and torch. If acetone is present at your welding flame, the weld will be ruined.

A standard acetylene bottle is about 40 inches long and about 12½ inches thick. It contains about 275 cubic feet of acetylene. Smaller bottles hold only 110 cubic feet. The acetylene in both types is compressed to 250 psi.

Pressure gages do not accurately measure the amount of acetylene remaining in a bottle. Weight calculations are more accurate. At 70°F., 14.5 cubic feet of acetylene in a bottle weigh one pound. Subtract the empty weight of a bottle from the weight of the bottle you're measuring. Multiply the weight difference in pounds by 14.5 and you have the number of cubic feet of acetylene remaining in the bottle.

Fusible safety plugs are in the valve fitting and in the bottom of an acetylene bottle. These plugs release the acetylene when the pressure becomes too high for safety.

Damaged or leaky cylinders either of oxygen or of acetylene should be carried to the fan tail and the gas contents gradually released so that they will be diffused away from the ship. In an emergency you may be ordered to heave the cylinders overboard.

SAFETY FIRST WITH ACETYLENE—

- KEEP SPARKS, FLAMES, AND HEAT AWAY from acetylene.
- NEVER TEST FOR LEAKS WITH AN OPEN FLAME. Use soapy water.
- TURN THE KEY ONLY ½ TURN WHEN YOU OPEN THE BOTTLE VALVE.
- ARRANGE BOTTLES IN CARRIER SO THAT VALVE OPENINGS POINT IN OPPOSITE DIRECTIONS.

Accidents are the result of carelessness and ignorance. Learn the rules and be careful when you use the equipment.

PRESSURE REGULATORS

Acetylene and oxygen pressures to the torch are controlled by precision-built REGULATORS. The regulators act to step down the pressure and to maintain the desired pressure applied through the hoses to the torch. There are two general types of regulators—single-stage and double-stage. The double-stage regulator is best because the pressure is reduced in two steps or stages. This en-

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ables the regulator to maintain a uniform pressure at the torch.

A regulator has two GAGES—one HIGH-PRESSURE to indicate bottle pressure, and one LOW-PRESSURE to indicate working pressure. They are shown in figure 45.

After both regulators are installed and the hoses and torch connected, the OXYGEN bottle valve is COMPLETELY opened. The ACETYLENE bottle valve is opened ONLY ONE-HALF turn.

Oxygen regulators have RIGHT-HAND threads and should be painted GREEN. Acetylene regulators have LEFT-HAND threads and should be painted RED. Never try to use an oxygen gage for acetylene or an acetylene gage for oxygen. Also, never use a low-pressure gage to replace a high pressure gage.

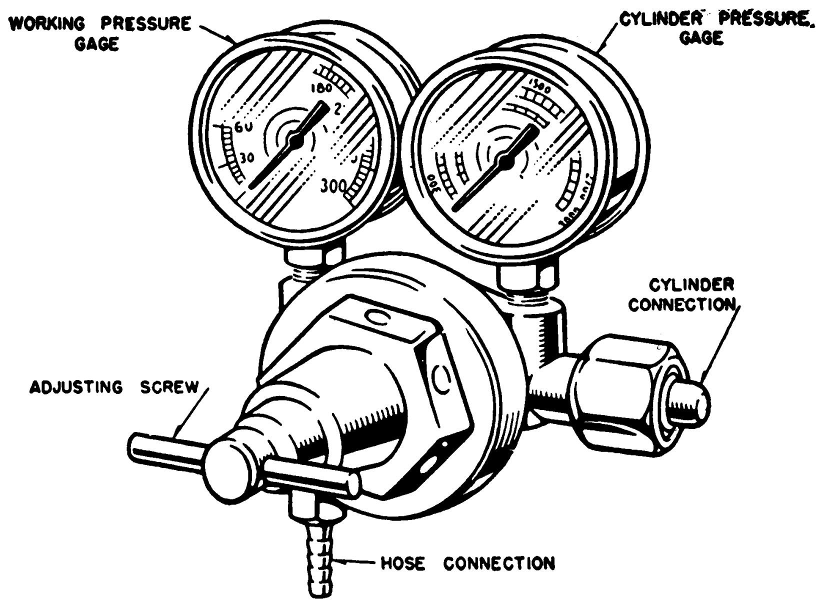

Figure 45.—Pressure regulator for oxygen.

Do not attempt to repair or dismantle gages or other parts of regulators. This is a job for expert instrument mechanics. REPLACE the defective part if a gage leaks, or if you have other trouble with a regulator. The defective part should be turned in for repair at a Navy Yard or to a repair ship.

Protect your regulators as you would a sore thumb. This is particularly important when you are moving your welding outfit from place to place—passing it through doors and hatches and up ladders. Keep the bottle valves closed when you're moving the outfit.

NEVER use the valve or regulator as a handle for moving, carrying, or hoisting a gas bottle.

USE NO OIL ON REGULATORS. Pressure of gas in the regulator will cause an explosion if any oil is present.

WELDING HOSE

The hoses which connect the regulators to the torch are specially manufactured so they will be flexible, pressure-resistant, and absolutely non-porous. TWIN HOSES are those which are molded together so they will be convenient for stowage and handling.

Oxygen hoses are GREEN—acetylene hoses are RED. Labels are often molded into the hoses for further identification. Size of hose is measured by the inside diameter. The commonly used sizes are 3/16″, 1/4″, and 3/8″.

Figure 46.—Hose connections.

Standard hose connections are illustrated in figure 46. Size of the fitting is determined by inside diameter. Notice the difference in design of the oxygen and acetylene

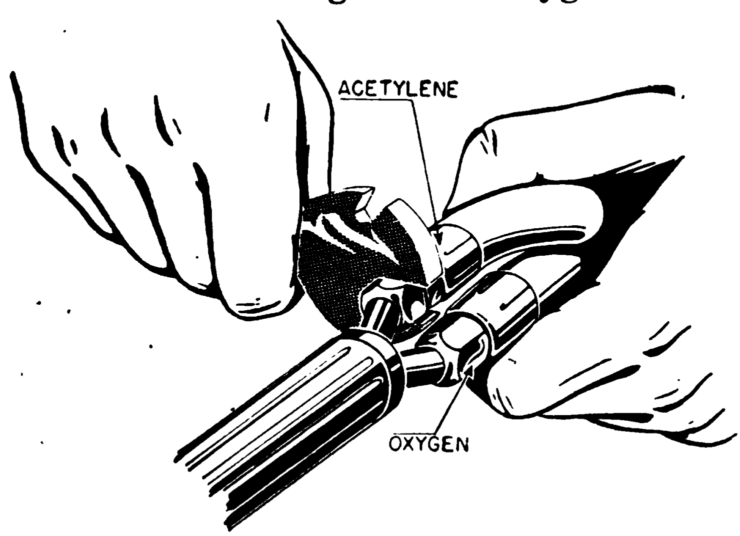

Figure 47.—Connecting hose to torch.

fittings. Remember that the nut with the groove has a left-hand thread—it's the acetylene fitting. A HOSE CLAMP or FERRULE holds a hose end tightly on the fitting nipple.

The method of connecting the hoses to the torch is illustrated in figure 47.

Before you open the regulators, take a look at the two hoses and their fittings. Look for leaks, loose connections, and worn places. Use SOAPY WATER to test for leaks. Brush it on, as in figure 48, while the hose is under a pressure of one psi. Bubbles will indicate leaks.

Figure 48.—Testing for leaks with soapy water.

NEVER TEST FOR LEAKS WITH A MATCH OR WITH ANY OPEN FLAME. Always use soapsuds.

Do not attempt extensive repairs to hoses. If the hoses are in bad shape, replace them. Try to maintain hoses in good condition by keeping them free of oil and grease. Avoid pulling them around corners. When the welding outfit is secured, arrange the hoses so that they are off the deck and out of the way, BUT—don't coil them on the regulators.

WELDING TORCHES

All of the equipment described so far has just ONE purpose—to provide the proper amount of oxygen and acetylene for the welding torch. Oxygen and acetylene are kept SEPARATE until they reach the MIXER which is near the forward end of the torch, as you can see in figure 49. Other parts of the torch are the NEEDLE-VALVES, the HANDLE and the TIP. Torches are made under such trade names as Airco, Oxweld, Purox, and Presto-Weld. They may differ somewhat in construction but they all have the same function—to provide a suitable mixture of oxygen and acetylene for the welding flame.

MEDIUM-PRESSURE torches require approximately the same (balanced) oxygen and acetylene pressures. The

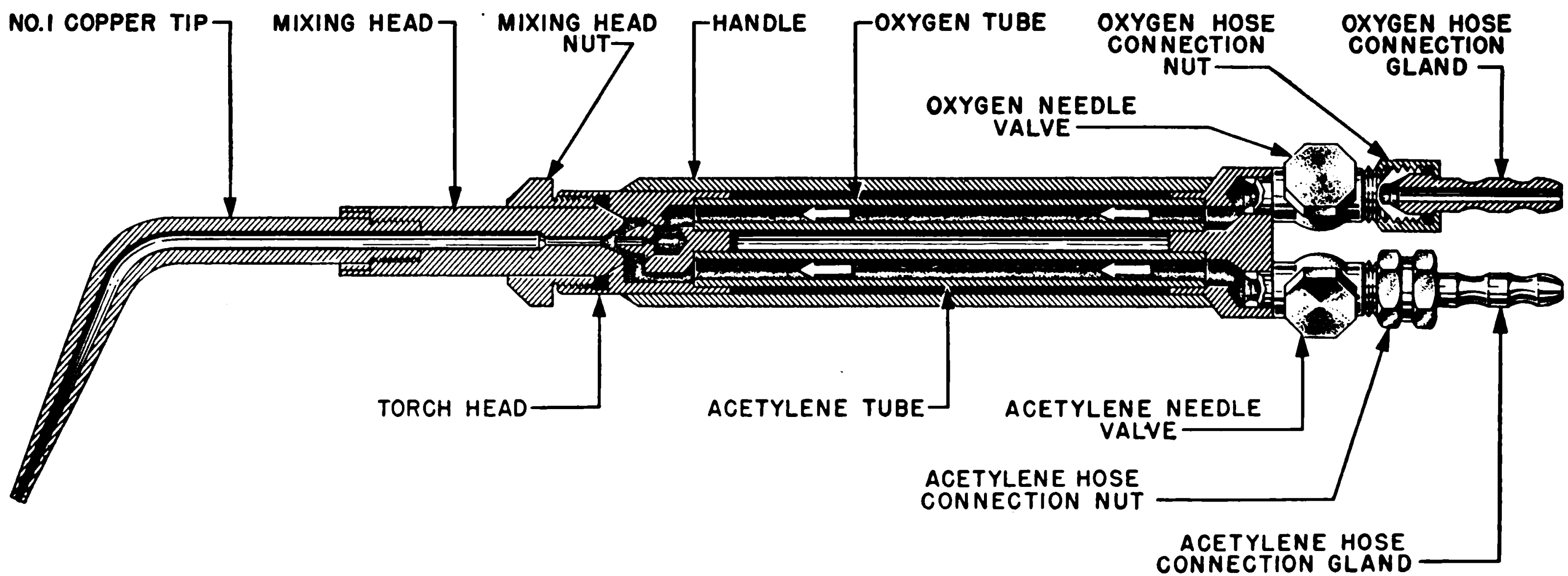

Figure 49.—Medium-pressure torch.

flame of this torch is easily controlled and adjusted with the needle-valves. There is little danger of a flashback when you use this type of torch.

LOW-PRESSURE torches operate on the INJECTOR PRINCIPLE. The acetylene pressure is always low (about 1 psi) and the oxygen pressure is relatively high (up to 30 psi). The velocity of the oxygen is increased as it's conducted through a small hole in the injector. (See figure 50.)

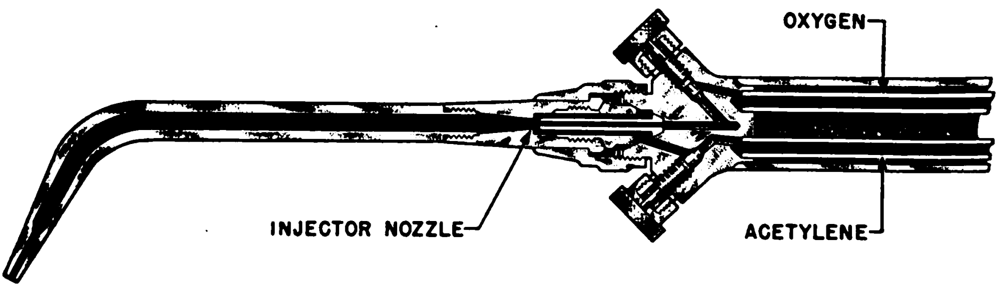

Figure 50.—Low-pressure torch.

With this high velocity, the oxygen creates a SUCTION EFFECT which sucks the acetylene into a small expansion chamber. This chamber, being larger than the injector hole, causes a reduction in the velocity of the mixture as it passes on to the torch tip to be burned.

Both medium-pressure and high-pressure torches produce mixtures of about half oxygen and half acetylene at the tip. The same flame variations (types of flames) are obtainable with both torches.

These torches are durable and well made, but that doesn't mean that they are foolproof. Stow your torch carefully. Always put it up when you are through with it—don't leave it hanging on a regulator. Never use it as a hammer or pry-bar.

Ordinarily you won't have any trouble with the inside mechanism of the welding torch. If you do have trouble, it probably will be caused by dirt in the valves, mixer, or tip. Threaded parts are easily dismantled and wiped clean. Avoid bending or denting any parts, especially threads and valve seats. Needle-valve seats may be cleaned with a pencil eraser but don't overdo it—clean only when necessary.

TORCH TIPS

The tip of the torch is the part through which the gas mixture leaves the torch to be burned. Most Navy torches

have interchangeable tips. The size of the tip is designated by the diameter of its orifice (hole), expressed in thousandths of an inch, or by TIP NUMBERS. The smaller the tip number, the smaller the orifice. The smallest tip number is #0 and the largest is #15 in the most commonly used system. Most of your work will be done with tips ranging in size from 2 to 10. (Another system uses the numbers 20, 21, 22, etc.)

Torch tips frequently become clogged. When this happens, clean the tip with a piece of soft copper or brass wire or use a regular TIP DRILL. (See figure 51.) This cleaner is a small drill with a hex-nut head. Use the tip

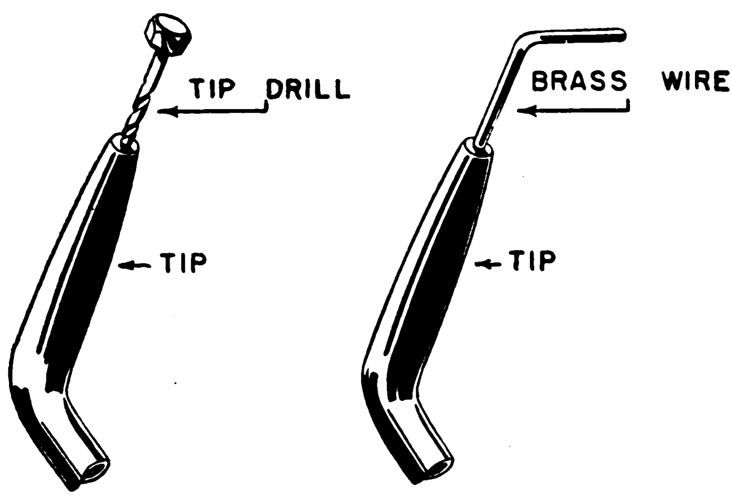

Figure 51.—Cleaning the torch tip.

cleaner by pushing it into the hole—don't rotate it. Avoid using the wrong size by following the guide in figure 52. That table is also valuable as a guide for selecting tips and pressures for use with a medium-pressure torch.

The recommendations in figure 52 won't always work. A fast, highly-skilled workman uses a larger tip than a beginner. Also—you must allow for the HEAT CONDUCTIVITY of metals. Some metals conduct heat rapidly and require a large tip to provide sufficient heat for welding.

It's a good practice to start off with the recommended tip and pressures and then make changes if necessary. As you gain experience you will automatically select the right tip and pressures.

Never use the torch tip as a hammer to knock off burnt metal, oxides or scale. The torch tip is comparatively soft and will be seriously damaged if used as a hammer.

FLASHBACKS AND BACKFIRES

A FLASHBACK occurs when flame enters the torch and penetrates through the mixer, valves and hoses, and sometimes as far back as the regulators. The causes of flashbacks are improper manipulation of the bottle valve and regulators, improper torch lighting, and incorrect manipulation of tip and valves. A flashback explosion occurs because the oxygen and acetylene get mixed BEFORE they are supposed to and are ignited at the tip.

Avoid dipping the torch tip into the puddle of molten metal. Dipping will cause the gas mixture to be blocked

TORCH TIP GUIDE

Tip No.	Orifice Diameter	Cleaning Drill Size	Acetylene Pressure	Oxygen Pressure	For Metal Thickness
0	0.025	74	1	1	1/32"
1	0.031	69	1	1	1/16"
2	0.038	64	2	2	1/8"
3	0.046	57	3	3	1/4"
4	0.055	55	4	4	3/8"
5	0.067	52	5	5	1/2"
6	0.076	49	6	6	5/8"
7	0.086	45	7	7	3/4"
8	0.096	42	7	7	1"
(Table applies to Airco tips used on steel)					

Figure 52.—Torch tip guide.

so that it will burn or explode inside the tip—or farther back—thus causing a flashback or a backfire.

You can avoid flashbacks by following the correct procedures for opening valves, adjusting regulators, and lighting the torch. Learn the correct procedures which are given in this chapter. Follow them EVERY TIME YOU USE THE TORCH.

BACKFIRES are not as serious as flashbacks because the flame does not reach back farther than the mixer. The usual result of a backfire is that the flame is extinguished with a loud pop, similar to an automobile backfire. Sometimes backfires are caused by overheating the torch tip. Such a backfire might occur when you're welding in a re-

stricted corner or angle or when you're welding a preheated casting. When you have a backfire, shut off the OXYGEN needle-valve of the torch IMMEDIATELY. The acetylene may then be re-lighted in the usual manner.

Avoid both backfires and flashbacks. In addition to being dangerous to YOU and OTHERS, they damage your equipment and reflect on your ability as a welder.

ASSEMBLING THE EQUIPMENT

When you're setting up your welding equipment, follow a DEFINITE PROCEDURE. Assume that you're starting from scratch, with all equipment disconnected. Here's the procedure—

Stand clear and crack the valve of the oxygen bottle. Open it just a little and close it IMMEDIATELY. This will blow dirt out of the fitting. Wipe the connection seat with a clean cloth.

Figure 53.—Cracking a bottle valve.

Do the same thing with the acetylene bottle valve, making sure that you stand to one side of the opening.

Attach the regulators. Tighten the nuts securely with a snug-fitting wrench.

Connect the RED hose to the acetylene regulator and the GREEN hose to the oxygen regulator. Tighten the nuts securely.

Release the regulator screws of both regulators.

STAND CLEAR and SLOWLY open the bottle valves—oxygen FULL OPEN and acetylene ONLY ½ turn.

Blow out the oxygen hose by releasing and quickly closing the regulator screw.

Repeat this with the acetylene hose.

Connect the RED hose to the acetylene fitting of the torch and the GREEN hose to the oxygen fitting of the torch.

Select and install the tip.

Adjust the ACETYLENE working pressure with the torch needle-valve open. Close the needle-valve as soon as

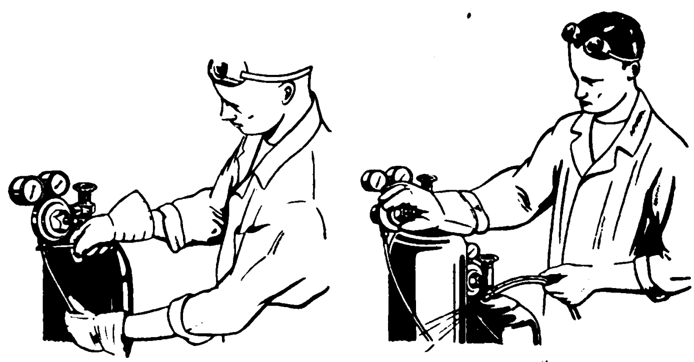
ATTACHING HOSE BLOWING OUT HOSE

Figure 54.—Attaching and blowing out hose.

the regulator is adjusted. Then adjust the oxygen pressure in the same manner. NEVER HAVE BOTH TORCH VALVES OPEN AT THE SAME TIME unless the flare is burning.

LIGHTING THE TORCH

Open the ACETYLENE needle-valve of the torch approximately ¼ turn.

Light with a spark-type lighter. Keep hands from in front of tip and wear gloves to prevent burns.

Open the oxygen needle-valve and adjust the flame. You may have to increase the acetylene to get the desired flame adjustment.

FLAME ADJUSTMENTS

The three types of welding flames are pictured in figure 55. When in doubt, use a NEUTRAL FLAME—that's the welder's general rule. The neutral flame requires about equal parts of oxygen and acetylene. Notice that

it has a FULL INNER CONE but no "feather" (intermediate cone).

The neutral flame, when used on steel, creates a clear, quiet puddle. It burns without cloudiness, boiling, or foaming. The welded metal is sound and ductile—not

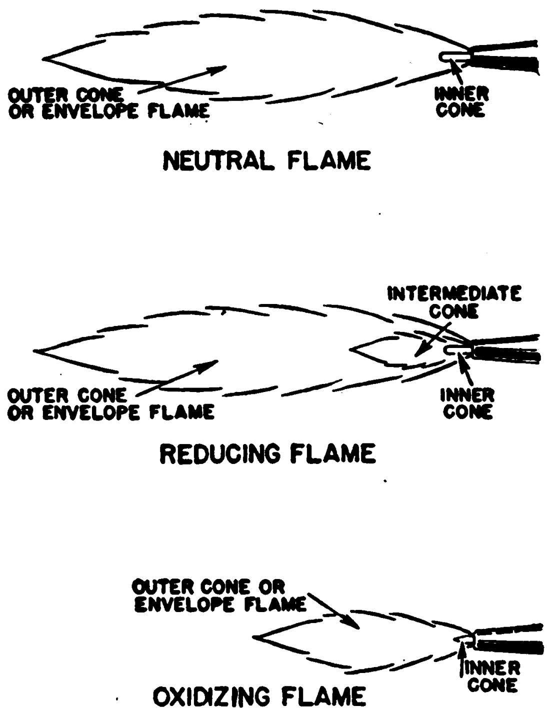

Figure 55.—Types of flames.

brittle and porous. The neutral flame is normally used when you're welding—

Cast iron, gray
Semi-steel
Cast iron, white
Corrosion-resisting steel
    (Cr. 18–26%)
Nickel steel
    (Ni. 7–12%)

Copper
Aluminum (cast)
Aluminum (sheet)
Nickel (cast)
Nickel (sheet)
Monel
Bronze facings

A CARBURIZING or reducing flame is obtained when you use more acetylene than oxygen. A slight excess of acetylene causes a small feather to form at the end of the inner cone. The greater the amount of the excess, the greater the size of the feather. The carburizing flame causes some carbon to be added to a weld. The addition of carbon is indicated by a boiling action of the molten metal.

The feather of this type of flame is small—just large enough so you can be SURE that the flame is NOT oxidizing. Use a slightly carburizing flame on these metals—

Carbon steel (up to 0.55%)	Chrome-vanadium steel
Cast steel	Chrome-molybdenum steel
Nickel steel	Chrome-nickel
Chrome steel	Hard facing alloys

An OXIDIZING flame requires more oxygen than acetylene. This flame is easily recognized by the "pinched" and pointed appearance of the inner cone. The oxidizing flame causes foaming and sparking of the molten puddle. The resulting weld is brittle because the steel is burned until it is porous.

A SLIGHTLY oxidizing flame is used when you are doing NON-FERROUS BRAZING and when you are welding the copper alloys—SHEET BRASS, CAST BRASS, and BRONZE. You use this type of flame because you want to be sure that no carbon is added to the weld metal.

SECURING THE WELDING EQUIPMENT

Always follow this procedure for cutting-off the torch and securing the welding set-up—

Close acetylene needle-valve of torch.

Close oxygen needle-valve of torch.

Close acetylene bottle valve.

Close oxygen bottle valve.

Open torch acetylene valve (keep oxygen valve closed) to drain hose and torch. Release acetylene regulator adjusting screw. Close acetylene valve of torch.

Open oxygen valve of torch (keep acetylene valve closed) to drain hose and torch. Release oxygen regulator adjusting screw. Close oxygen valve of torch.

Close both bottle valves.

The bottle valves need not be closed if the torch is to be used in a short time. The valves ALWAYS should be closed if you leave the vicinity of the equipment and when you secure from work.

All equipment should be secured in such a manner that it cannot be damaged accidentally by passing personnel or by the pitch and roll of the ship. Bottles should be kept upright. If the bottles are used in a portable cart or rack, securely lash or chain them in place.

WEAR YOUR GOGGLES

Take a look at a pair of welding goggles which have been in use for some time. You'll see a lot of small specks and pits on the face of the lens. The specks are small particles of iron oxides which would have caused injury to the eye if goggles had not been worn. The pits are caused by flying particles of hot metal—even more dangerous than the oxides.

Welding goggles give your eyes another sort of protection, too. The lenses are specially made to stop the infra-red and ultra-violet rays of the flame. Most lenses have a greenish tinge; some are bluish in color. The colored lens is protected by a plain glass lens.

Lenses are designated by number. A number 1 is very light and is seldom used. A number 12 lens is extremely dark—too dark for welding with the oxyacetylene torch.

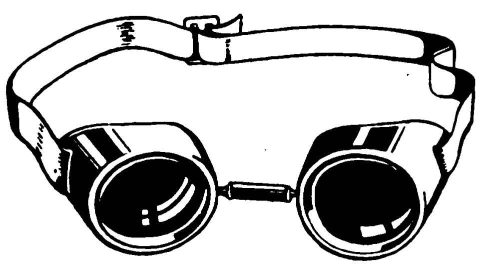

Figure 56.—Goggles.

It's used with the arc-welder. For gas welding, you'll use lenses numbered 4, 5, or 6. How can you tell which lens to use? Here's how—

> Select the lens you think best for the job. Go ahead and weld a few minutes—then stop. If you had to strain your eyes at all, the lenses are too dark. In that case, try the next smaller number. If you see white spots in front of your eyes when you remove the goggles, the lenses are too light. Try the next larger number.

Goggles should fit snugly. Pick out a pair that FITS YOUR face and your eyes. Equip these goggles with the desired lenses and use THAT pair all the time. It's bad sanitary and safety practice to exchange goggles with other workmen.

OTHER WELDING EQUIPMENT

GLOVES are worn to protect the hands from flying metal and from the heat of the flame. Regular issue leather gloves, with long gauntlets, are satisfactory for most jobs. Special gloves, of asbestos or chemically-treated canvas, may be available. Keep your gloves CLEAN—don't use them when they become greasy and oily.

WRENCHES used on valves and fittings should be kept clean and in good condition. Special short-handled wrenches are usually provided by the manufacturers of the equipment. Long wrenches would give you too much leverage on the brass fittings. The wrench opening should fit snugly over the part being adjusted, loosened, or tightened.

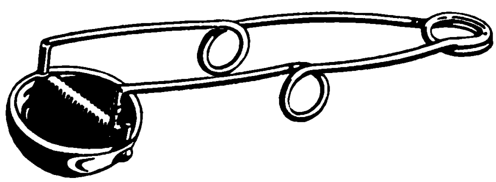

Figure 57.—Sparklighter.

WIRE BRUSHES should be kept handy for cleaning dirty metal and for removing excess flux and scale after welding.

A SPARKLIGHTER (figure 57) is used to light the torch. DO NOT USE MATCHES. Lighting with a match is DANGEROUS because the sudden puff of flame may burn your hand. Shore installations with bench units may have pilot lights for lighting the torch.

WELDING DONT'S

A tomcat may have nine lives—the average welder has only one. Nevertheless, he may outlive the cat if he remembers what to DO and what NOT TO DO. Here are some of the things you should NOT do—

DON'T use oil or grease on ANY welding equipment.
DON'T light the torch with BOTH needle-valves open.
DON'T use leaky apparatus.
DON'T allow kinks to form in your welding hoses.
DON'T weld without your goggles.
DON'T hang your torch on the regulators.
DON'T weld ANY KIND of fuel container.
DON'T weld unless you have a fire watch.

DON'T forget to station a man at the bottle valves when you're welding in a confined space.

DON'T use makeshift tools.

DON'T tamper with the fusible safety plugs of the bottles.

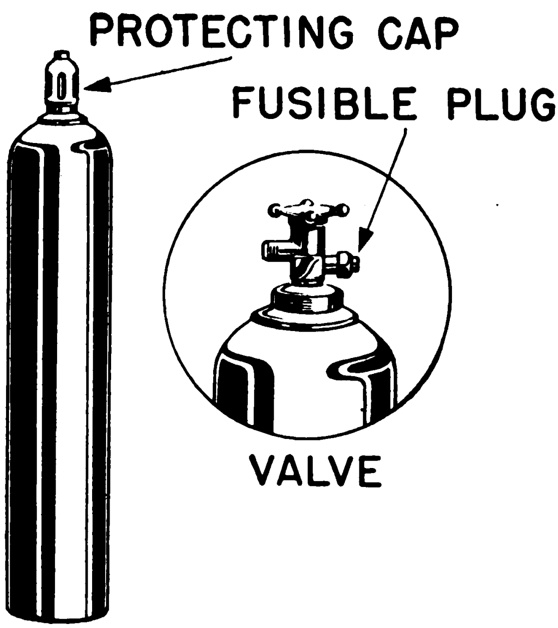

Figure 58.—The fusible safety plug.

DON'T try to repair valves and regulators. Replace unsatisfactory equipment IMMEDIATELY.

DON'T get rough with gas bottles. Baby them at all times.

DON'T hoist bottles by attaching lines to the valves or regulators—use a cradle.

DON'T weld CORED CASTINGS or other enclosed spaces without proper venting. Heating of an entirely enclosed space may cause an explosion.

DON'T weld in a confined space if the work can possibly be taken to a place where there is plenty of air. If you can't move the work, set up a portable ventilator.

DON'T assume anything. BE SURE BEFORE YOU START TO WELD.

CHAPTER 4

GAS WELDING (FERROUS)

LEARNING TO WELD

There's only one way you can learn gas welding—that's with a welding torch in your hand. There is an art to this type of welding that is not readily acquired from other people or from reading books. The basic skill of gas-welding is TORCH MANIPULATION—the way you move and control the welding flame. The ONLY way you can learn is by PRACTICE. Then comes MORE PRACTICE. Luckily, the practice is not monotonous—each practice job is a challenge to YOU. And it's surprising how much satisfaction is derived from making a good weld.

While practice is essential, there is a lot of INFORMATION and THEORY that you might have trouble with—IF you had to dope it out for yourself. That's why it's a good idea to study this chapter carefully and to get advice from experienced Metalsmiths.

Use this chapter as a guide for your practice. If you are a complete beginner, start with the first job and do all ten types of jobs suggested. Work on one problem until you have mastered it. Then move on to the next job.

Weld in the shop when you can—it's a lot easier than welding away from the shop. It's a tough job hauling 350 pounds of welding equipment up ladders, and through

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doors and hatches. Also, in the shop you'll have a handy bench which is made especially for welding. The bench has a fire brick top and a rack or hook to hold your torch. Your welding accessories—rod, tips, goggles, lighter, clamps, files, pliers, and flux—are stored nearby so they are readily accessible.

Most of your welding will be done on mild steel—low-carbon or medium-carbon. It happens that this material is about the easiest there is to weld. No flux is required. Most of your work will be with SHEET stock. Sheets are 1/8" thick or less. PLATES are over 1/8". You'll do some plate welding with gas, but most of this type of welding will be emergency work. Ordinarily you'll use an arc-welder on these heavy steel plates.

For your practice work, use pieces of scrap sheet steel. The petty officer in charge of the shop will furnish you with practice metal or tell you what you can and cannot use.

MEANING OF WELDING TERMS

If you have been around welders much you have heard them use such terms as penetration, oxidation, root, and fusion. To become a good welder you must learn the meaning of these and other commonly used welding terms, especially the ones listed and defined here—

BACKHAND WELDING—directing the flame toward the weld already formed; the best technique for welding plate. See figure 59.

BASE METAL—the metal to be welded; sometimes called the "parent metal."

BEAD—weld metal deposited in one pass.

BOND—the junction of the weld metal with the base metal; the line of fusion.

CARBURIZATION—addition of carbon to weld metal; caused by excess of acetylene in flame.

DEPOSITED METAL—added filler metal; usually added from a welding rod.

FLUX—material or gas used to dissolve and prevent the formation of oxides, nitrides, or other undesirable material in the weld area.

FOREHAND WELDING—directing the flame in the direction you're welding and AWAY from the weld already made. See figure 59.

FUSION WELDING—joining metals by melting adjoining surfaces, with or without the addition of extra metal. The commonest forms of fusion welding are gas-welding and arc-welding.

HEAT-AFFECTED ZONE—section of base metal whose properties are changed by the heat of welding.

OVERLAP—metal built up above the base metal and not properly fused to the base metal. See figure 60.

OXIDATION—combustion (burning) of the elements of the metal, caused by oxidizing flame (flame having too much oxygen).

PASS—one trip along the line of the weld.

PEENING—hammering the weld metal.

PENETRATION—depth of fusion below surface of base metal.

POSTHEATING—heat applied after welding.

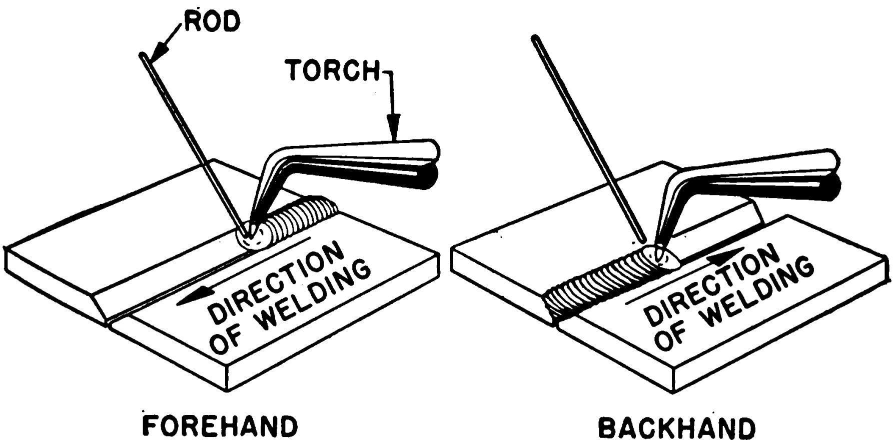


Figure 59.—Forehand and backhand welding.

PREHEATING—heat applied before welding.

ROOT, WELD—limit of fused metal in direction away from the surface, or face, of the weld; the deepest part of the weld.

SEAL WELD—used for water, oil, or air-tightness rather than for strength.

SLAG INCLUSION—undesirable non-metallic material which is trapped in weld metal; causes weld to be porous and weak.

TACK or TACK-WELD—a weld for assembly only, not for strength.

THERMAL STRESS—internal stress caused by lack of uniformity of heating and cooling.

TOE—junction of base metal and weld metal on surface of weld. See figure 61.

UNDERCUT—undesirable thinning of base metal. See figure 60.

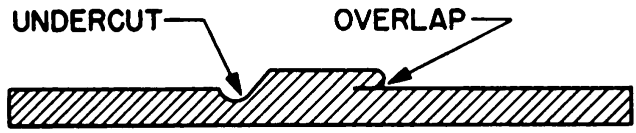


Figure 60.—Two kinds of faults.

WEAVING—method of depositing weld metal by oscillating flame and rod.

WELD, PARTS OF—see figure 61.

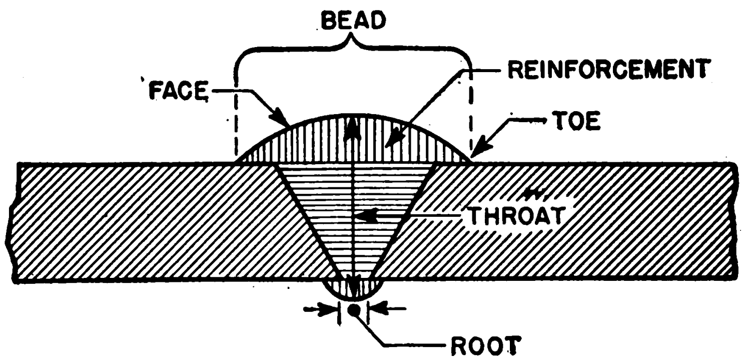


Figure 61.—Parts of a weld.

WELDMENT—an assembly whose parts are joined by welding.

WELD METAL—fused mixture of the filler metal and the base metals.

FILLER ROD FOR STEEL

(Navy Spec. 46R4)

Because most of your welding will be done on low and medium-carbon steels, use a filler metal specified as CLASS I, TYPE *A*. It's available in rod form in diameters of $\frac{1}{16}''$, $\frac{3}{32}''$, $\frac{1}{8}''$, $\frac{5}{32}''$, $\frac{3}{16}''$, and $\frac{1}{4}''$. The smaller sizes are covered with a thin coating of copper.

You may have some Class I, Types *B* and *C* rods. Use them only on "Chrome-Moly" steels.

The most complete information available on welding rod and other welding supplies (both gas and arc), is contained in a publication of BuShips entitled GUIDEBOOK TO THE SUPPLY AND USE OF WELDING AND BRAZING MATERIALS FOR THE NAVAL SERVICE. Your supply officer has a copy.

Refer to it when you are in doubt as to what to use.

Use welding rods to the last inch by welding short lengths together. Do not waste them. Avoid laying down a hot rod. After you've picked it up by the wrong end once, you won't do it again. And your shipmate won't appreciate it if you're responsible for burning his fingers.

PRACTICE JOBS

Ten basic sheet metal welding jobs are given here for practice purposes. If you are a beginner, do them in the order in which they are presented. By the time you have finished all ten jobs, you'll be able to manipulate the torch properly to secure the correct penetration and fusion.

All these practice welds should be made on pieces of low-carbon sheet steel about 2 inches wide and 4 inches long. Each job should be made first with 1/8 inch metal, then repeated with 1/16 inch metal. Use the FOREHAND METHOD of welding on all ten practice jobs.

No beveling of edges is required. All surfaces to be joined must be clean and free of grease, oil, dirt, rust, and paint.

If you are a beginner, get help and supervision from a rated Metalsmith.

PRACTICE JOB 1

RUNNING BEAD WITHOUT FILLER

Take a look at job number 1, figure 62. Here you're not going to weld two pieces together, but you're just going to try running a bead. Only one piece of stock 1/8" × 2" × 4" is required for this job. Place this piece on two fire bricks so that the part to be heated will not contact the bricks. Try a #2 torch tip first. Adjust the flame so that it is neutral or SLIGHTLY carburizing. Avoid an oxidizing flame.

If you're right-handed, START AT THE RIGHT and work to the left. Hold the torch tip so that it makes an angle of 45° with the line of weld. Keep it at an angle of 90° across the line of weld. Direct the INNER CONE of the flame at a point near the right edge of the metal and hold it there until a molten pool (puddle) forms. Keep the tip of the cone from 1/16 to 1/8 inch AWAY from the surface of the molten metal.

As soon as your puddle is formed, move the torch tip slowly forward with the weaving (oscillating) motion shown in figure 62. Both the forward movement of the torch tip and the weaving, sidewise motion must be uniform. If these movements are not uniform, the bead will be rough and irregular.

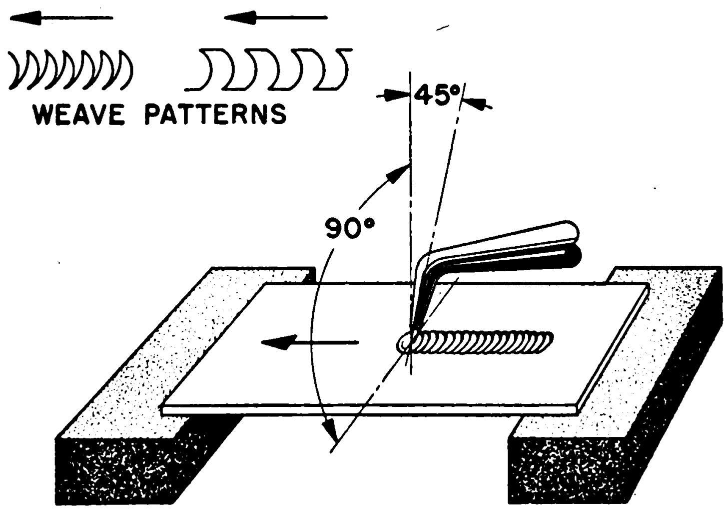


Figure 62.—Practice job number 1.

Don't be disappointed if the first job is a mess. You'll soon learn to control and direct the flame, so that you can make a uniform weld. Practice until your job looks like the one in the illustration.

A good bead weld must—

- Have uniform width of weld face.
- Have surface of weld slightly below surface of base metal.
- Have a thin film of oxides on each surface of the weld.

After you're able to do a good job on 1/8 inch metal, try this same job on 1/16 inch metal.

PRACTICE JOB 2

EDGE WELD WITHOUT FILLER

This job is pictured in figure 63. Set two pieces of 1/8 inch metal on edge between two fire bricks and TACK WELD the ends by fusing them together. Then, if you're right-handed, start a small puddle at the right and run your weld to the left. Melt and fuse the edges of the two pieces. Do not use a filler rod.

Repeat job 2 on $\frac{1}{16}$ inch stock. Change to a smaller tip.

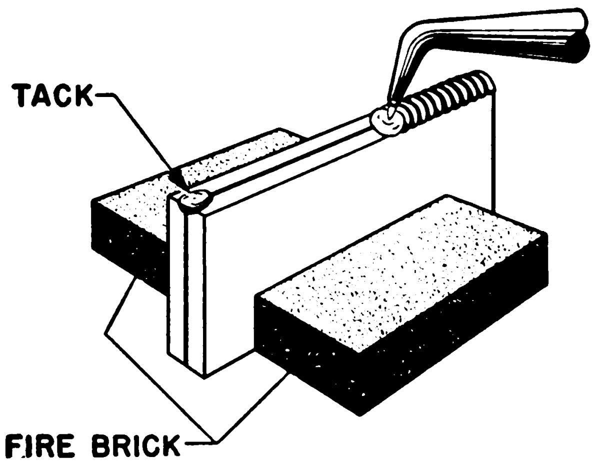


Figure 63.—Practice job number 2.

PRACTICE JOB 3

BEAD WELD WITH ADDED FILLER METAL

In this job the bead is built up by the addition of filler metal (welding rod). Otherwise it is similar to job 1. Use a $\frac{3}{32}$ inch mild steel rod. The weld should be built up about 25 percent or an amount equal to $\frac{1}{4}$ the thickness of the stock.

Start the puddle as in job 1. As soon as the puddle is formed, add the end of the welding rod to the middle of it,

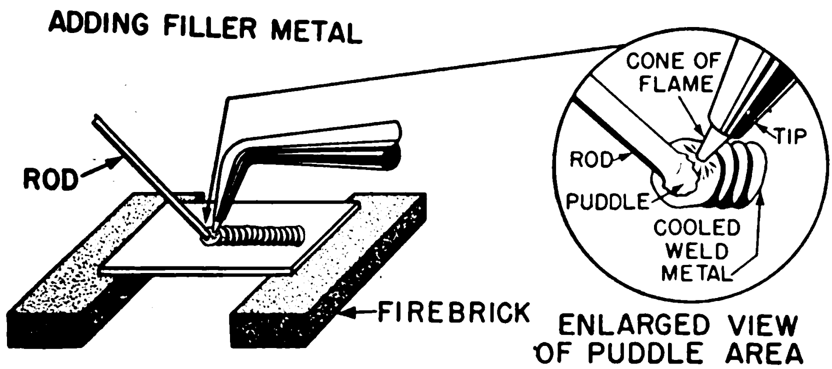


Figure 64.—Practice job number 3.

as pictured in figure 64. Keep the inner cone of the flame weaving as in job 1. Stir the rod in the puddle.

The movement of the rod should be opposite to that of the flame. When the flame is on one side of the puddle, the

rod should be on the other side. And stir the end of the rod IN the puddle—NOT above it. Avoid directing the flame at the end of the rod. Let the puddle melt the rod.

Direct the torch flame so that it preheats the weld area uniformly, or you won't get good fusion. Hold and manipulate the torch just right or the weld you make will not be uniform and strong. Incorrect torch manipulation causes such troubles as UNDERCUTTING and OVERLAPPING.

When you're an expert with 1/8 inch stock, try the same job on a 1/16 inch sheet.

PRACTICE JOB 4

CORNER WELD

Now you're ready to weld two pieces of metal together. Place two pieces of 1/8 inch stock as shown at the left in figure 65 and tack-weld them at the ends. Leave a 1/16 inch space between the two edges. Let the tack welds cool, then place the job as shown at the right. Start the weld with a puddle in the same manner you started the welds of jobs 1, 2, and 3.

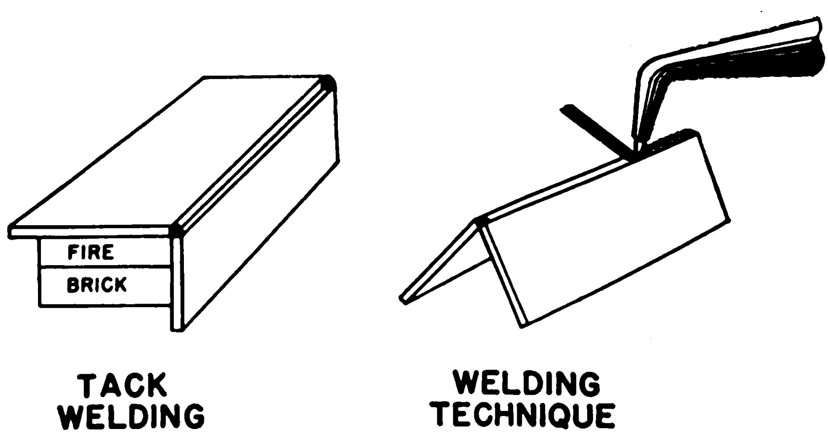


Figure 65.—Welding a corner.

Here's where you really begin to learn about FUSION and PENETRATION. Both have to be just right to get a good weld. Your finished job should look like the one shown in the center view, figure 66.

If your first corner looks like the one shown at the left, it's because you went TOO FAST or held the torch TOO FLAT —at too small an angle with the base metal. In other words, you didn't have enough heat in the right place at the right time.

A corner weld like the one at the right is caused by welding too slowly or by holding the torch at too great an angle with the base metal. This weld is better than the one at the left, but it still isn't good enough. Practice until you can make a weld that looks like the center one—a weld that has a uniform bead and uniform penetration. Then it's time for a check-up on the FUSION of the weld.

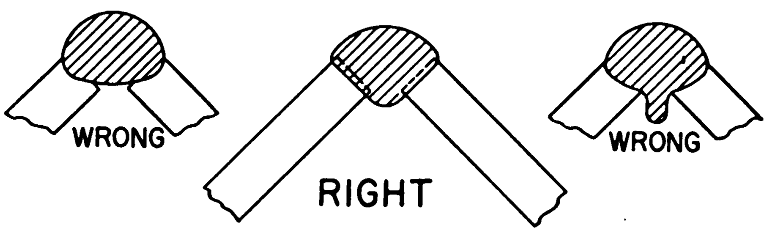


Figure 66.—Penetration and fusion of corner weld.

Test the fusion by laying the corner on a solid surface and hammering it out flat. The corner should flatten out without cracking or splitting.

If the weld does give way, it's probably because you did not handle your torch correctly. Did you heat both edges uniformly? Did you slight one edge? Or, did the flame adjustment shift (creep) without your noticing it? Be sure you KEEP the flame NEUTRAL or SLIGHTLY CARBURIZING and you won't have any flame trouble.

When you get a corner weld that withstands the flattening test with 1/8 inch sheet, try the same weld on two pieces of 1/16 inch stock. Leave no space between the two edges when you tack weld this lighter stock. And change to a smaller tip for the lighter metal.

PRACTICE JOB 5

BUTT WELD, FLAT POSITION

Butt welding in the flat position (figure 67) is used a lot on sheet metal. Tack the two pieces together leaving a gap of 1/16 inch. Then weld by the method used in job 4. The width of the bead should be from 2 to 3 times the thickness of the base metal.

Test this job by placing the metal in the vise with the weld slightly above the vise jaws. Bend the upper part of the job toward the weld so that the face of the weld is INSIDE the bend angle. Bend the upper part of the metal

far enough to form a right angle with the end in the vise. If the weld has the correct PENETRATION and FUSION, it will not crack or split.

Repeat this job with $\frac{1}{16}$ inch stock.

PRACTICE JOB 6

BUTT WELD, VERTICAL POSITION

To butt weld in the vertical position, prepare and tack two strips of metal as shown in figure 68. Hold the job

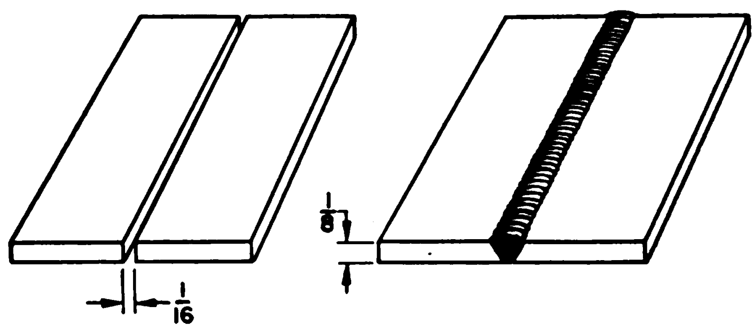


Figure 67.—Butt weld in ⅛" steel.

upright with a couple of fire bricks. As this weld is much harder to make than the flat position weld, you'll have to pay PARTICULAR attention to your penetration and fusion.

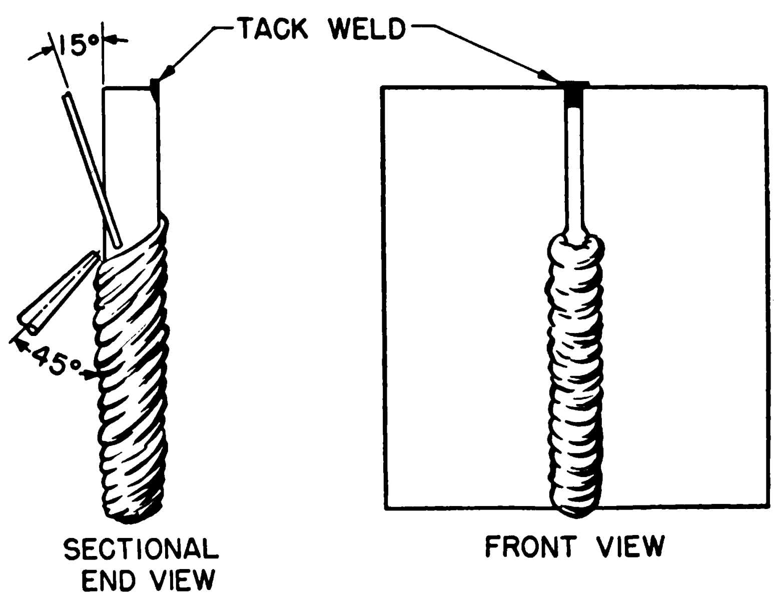


Figure 68.—Vertical butt welding.

Start the weld by forming a "shelf" at the bottom of the gap. Form your puddle on this shelf. Then proceed in

much the same manner as for a flat position weld. Move the puddle upward slowly and gradually. Hold the torch and rod as shown in the end view, figure 68.

As you weld, watch the "keyhole" shape of the gap that is formed just above the puddle. As long as this keyhole keeps its shape and moves upward above the puddle, your weld is going OK.

Don't expect your first effort at vertical welding to be a howling success—the chances are that it will look pretty bad. You may have to make several attempts before you really get the hang of it and produce a workmanlike job.

Repeat the job with $\frac{1}{16}$ inch metal.

PRACTICE JOB 7

BUTT WELD, OVERHEAD POSITION

Tack weld two pieces of $\frac{1}{8}$ inch steel and mount them in an overhead position (figure 69). Perhaps there is a jig

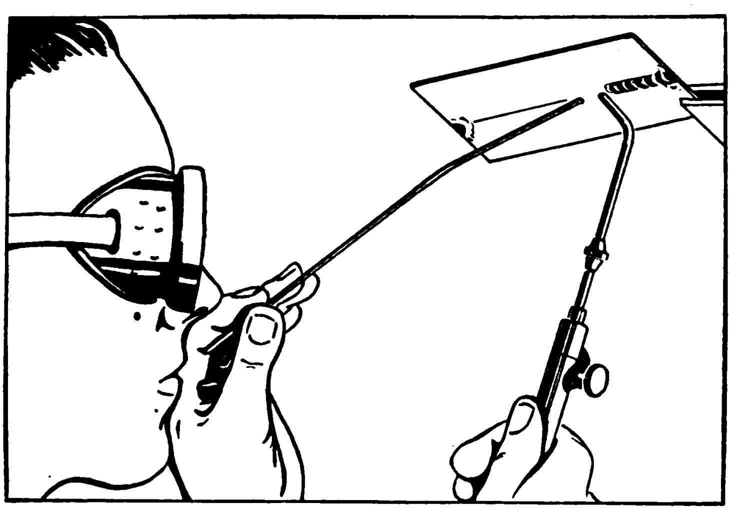


Figure 69.—Overhead butt weld.

in your shop that has been specially made for this kind of practice welding.

To make the overhead weld, stand directly under the joint and work so that the puddle moves toward you. Hold the torch with the tip pointing STRAIGHT UP, so the blowing action of the torch flame will help to keep the puddle from dropping. Use the end of the rod to stir the puddle and to move the puddle from side to side. The puddle must be kept small, or else a drop will form and fall from the weld.

You've noticed that oil or water won't fall from an overhead pipe until enough has collected to form a drop. The welding puddle of molten metal works the same way—it won't fall unless it forms a large drop.

PRACTICE JOB 8

FILLET WELDING A LAP JOINT

A fillet weld (figure 70) is made in much the same manner as the corner weld of job 4. For the fillet weld, lap the ⅛ inch thick pieces about 1 inch. Then tack weld both ends on the face of the base metal. Use a #3 tip.

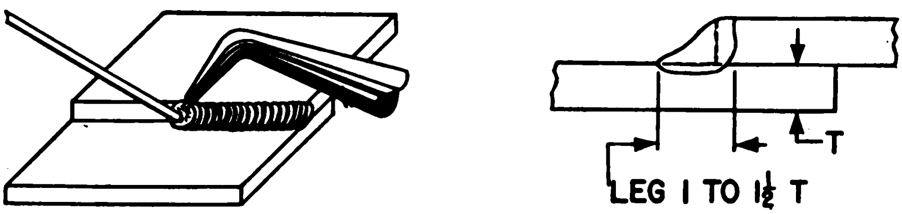


Figure 70.—Fillet weld of lap joint.

Make the weld in the flat position. Hold the torch so that the flame points into the corner formed by the edge of one piece and the surface of the other piece. Keep the puddle centered in the angle (corner). Avoid overheating the edge of the top piece by directing more heat toward the bottom piece than toward the top. If you can direct

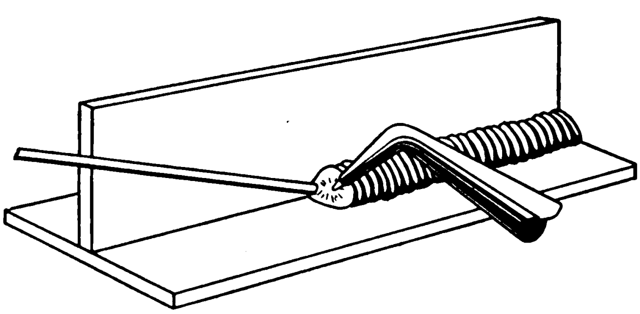


Figure 71.—Fillet welding a tee joint.

the flame in such a way that both legs of the weld are heated uniformly, your weld will have GOOD FUSION all the way through.

When you've mastered the fillet weld in the flat position, do the same job in the vertical and overhead positions.

PRACTICE JOB 9

FILLET WELDING A TEE JOINT

The fillet weld of a tee joint (figure 71) is made in the same general way as the fillet weld of the lap joint. Direct your flame so that both surfaces are heated equally and uniformly. Be extremely careful or you'll burn through one of the pieces.

Repeat the weld in the overhead and vertical positions.

PRACTICE JOB 10

SHEET STEEL TO STEEL PLATE

For welding SHEET steel to steel PLATE (figure 72), use one piece of sheet steel 1/8″ × 2″ × 4″ and one piece of steel plate 1/2″ × 2″ × 4″. Other sizes will do, just so you

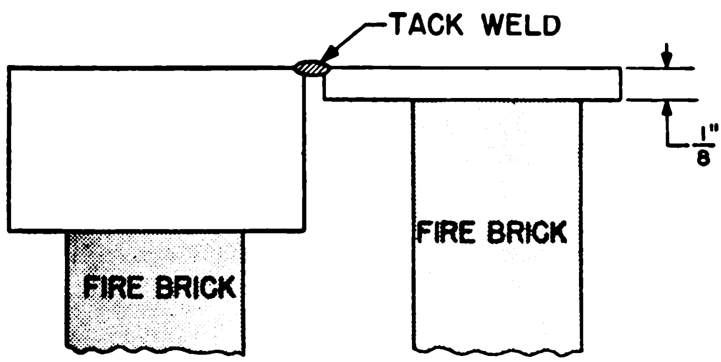


Figure 72.—Welding light to heavy metal.

have one thin piece and one thick piece. Use 1/8 inch filler rod. Tack weld the two pieces and you're ready to go.

Direct most of the heat toward the heavier metal—or the light piece will be burned. Use the forehand method of welding and direct the flame in such a way that the edge of the heavy piece is melted first. Enough heat will be conducted across to melt and fuse the edge of the thin piece. Allow more time for the puddle to form, and to travel, than you allow for two pieces of sheet metal.

OTHER SHEET METAL WELDS

The sectional views in figure 73 show a number of joint designs for welding sheet metal. Any of these is easy when you have mastered the other practice jobs. You may be required to make several of these welds as a practical test for your Third Class rating.

BUTT WELDING STEEL PLATE

FOREHAND METHOD

Ordinarily you will not do much gas-welding of steel plate—metal over 1/8 inch thick. Heavy stuff is usually arc-welded. However, there may come a time when no

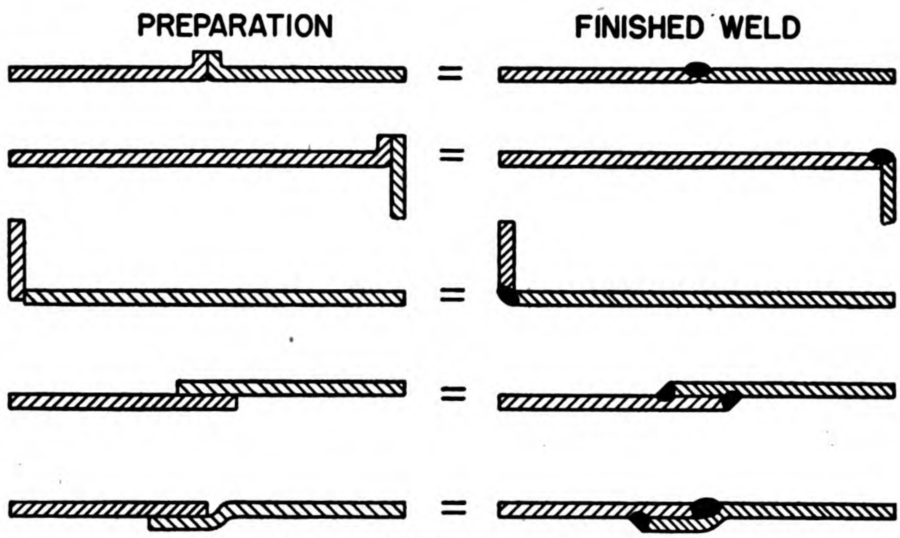


Figure 73.—Weld designs for thin sheet steel.

arc-welding equipment is available, or when there'll be no juice to run what equipment you may have. Then you'll have to fall back on your oxy-acetylene outfit.

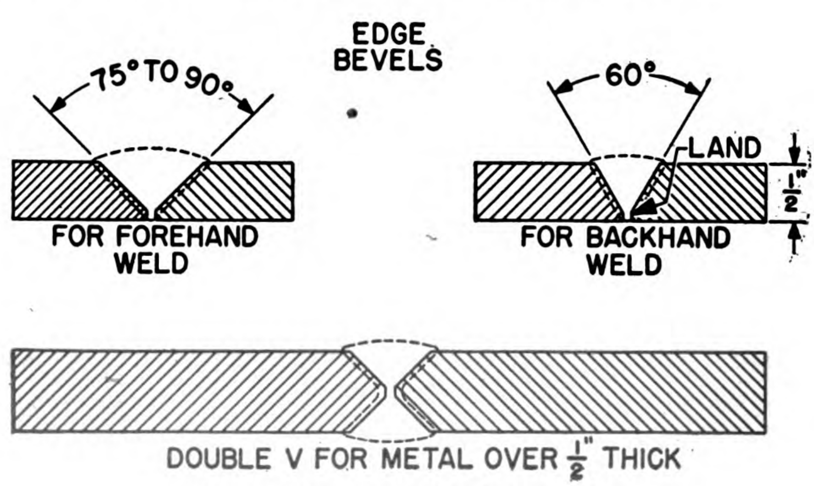


Figure 74.—Bevels for butt welds.

The basic principles of fusion, penetration, and flame control for gas-welding plate are the same as for welding sheet steel. But a number of other items must be considered. One of these is EDGE PREPARATION.

Butt joints in steel plate require EDGE-BEVELS. If the plate is less than ½″ in thickness you need to bevel only one edge. BOTH edges must be beveled on heavier plate.

Make the bevel of each edge at an angle of 30° to 45°. About 37½° is best for forehand welding, and around 30° for backhand. The bevel must have a small LAND. (See figure 74.)

Bevels may be cut on a grinder or with a gas cutting torch. The smoother and more uniform they are cut, the easier will be the welding. Torch-cut bevels must be surface-ground to remove the oxides and scale. A dirty surface means a bad weld.

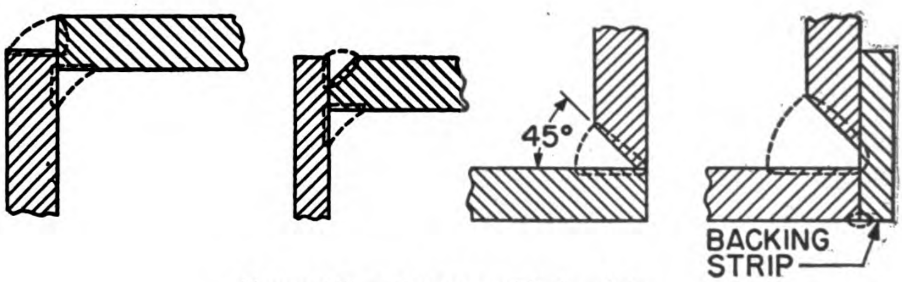


Figure 75.—Corner welds in plate.

Butt welds on beveled edges are made in much the same way as corner welds are made in sheet metal. Of course you must use a larger tip and the puddle will have to be larger. Both torch and rod must be oscillated (weaved)

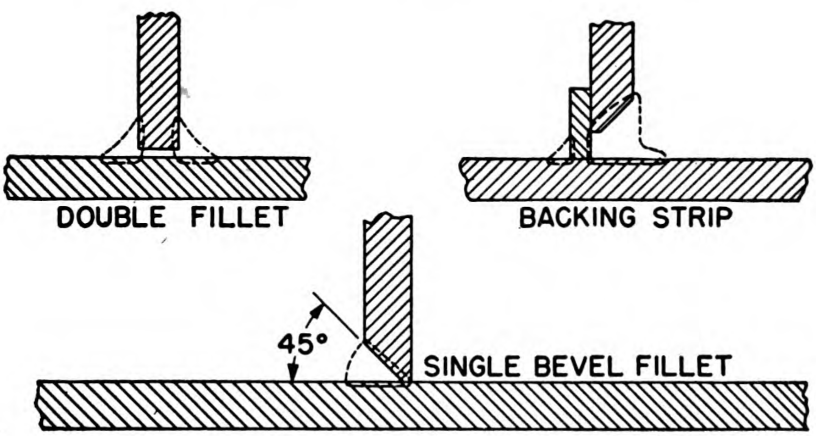


Figure 76.—Fillet welds on steel plate.

to secure the proper distribution of heat and weld metal, and to secure the proper penetration, fusion, and reinforcement.

When you tack-weld a beveled joint, make the tack ONLY about ½ the thickness of the base metal. A heavier tack will cause trouble when you start and finish the weld.

CORNER WELDS ON STEEL PLATE

FOREHAND METHOD

A variety of corner weld designs for plate is shown in figure 75. The design is influenced by the thickness of the parts and the strength required of the weld.

The joints in figure 75 are used when the thickness of the steel is more than ⅛ inch.

FILLET WELDS ON PLATE

FOREHAND METHOD

Fillet welds may be used on inside corner welds of steel plate if the joints are V-ed or J-ed as shown in figure 76. Tee joints may be V-ed or plain. The joint may be close or spaced ½ the thickness of the base metal.

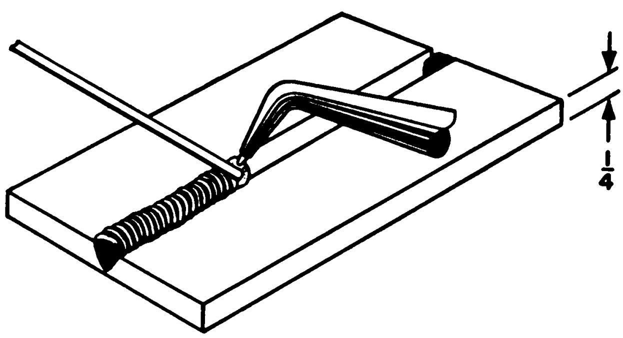


Figure 77.—Backhand butt weld.

Lap welds are done in the same way for heavy metal as for sheet metal. More than one pass may be required.

BACKHAND WELDING

So far you've made all your welds with the forehand technique. You pointed the flame AHEAD of the weld. For BACKHAND WELDING, the torch is pointed in the opposite direction—TOWARD THE WELD METAL, and AWAY from the unwelded part.

The backhand method is much faster but is more difficult to learn than the forehand method. The backhand technique works well on metal thicknesses above ⅛ inch. It's seldom used on sheet metal.

The V-groove for a backhand weld should be comparatively SHARP. The groove angle for the butt weld in figure 77 is 60° (30° for each edge).

For backhand welding use a tip at least one size larger than the tip you would use for forehand welding the same job. A larger tip is necessary because there is no flame preheating of the metal ahead of the weld.

To start a backhand weld, preheat the first two inches of the weld area to a dull red color. Then build up the weld metal to the proper shape at the end of the groove. When you've built up just enough reinforcement, start the rest of the weld. Weave the ROD. You do NOT need to weave the torch.

A few trial welds will help you determine the best angle at which to hold the torch. If the angle is too flat, you won't get sufficient penetration. If the angle is too great, you may burn through the metal.

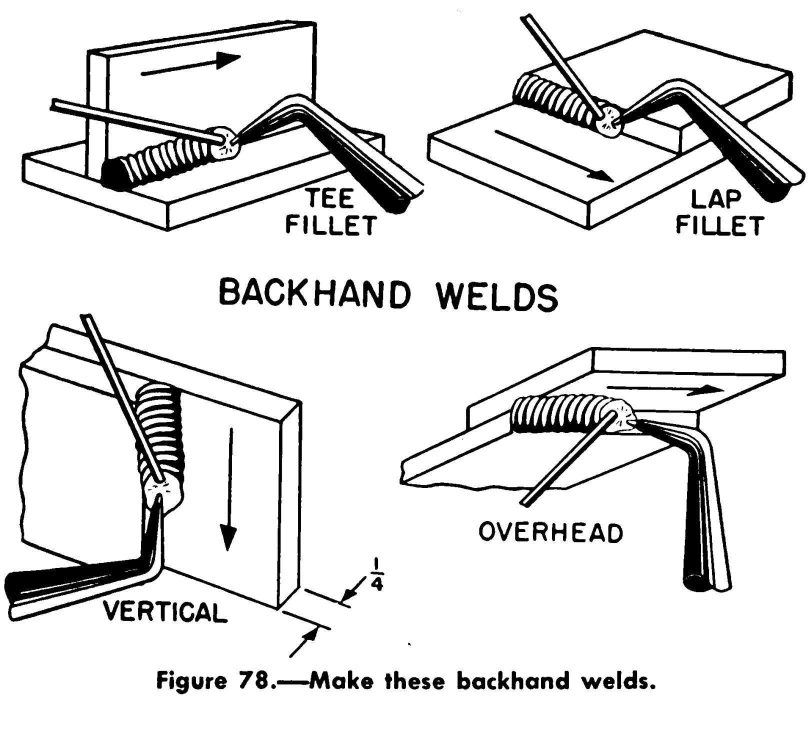


Figure 78.—Make these backhand welds.

Try the backhand welds pictured in figure 78.

PIPE WELDING (ROLLED)

Pipes are usually butt-welded in much the same manner as plate welds. The pipe ends must be beveled. New sec-

tions of pipe and weld-type fittings are beveled to 37½° when you receive them. Bevel cut sections of pipe with the cutting torch.

The pipes to be welded must be accurately positioned and alined. Straight length of small pipe may be tacked while held in a length of angle iron, as illustrated in figure 79. Four tack welds are used to hold the pipe ends in place for welding. These welds should be uniformly spaced. Keep their thickness down to not more than ½ the thickness of the pipe wall.

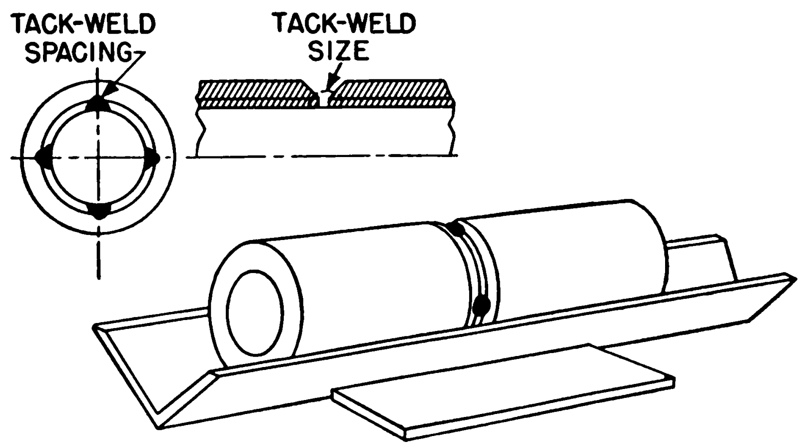


Figure 79.—Tack-welds for pipe.

If the pipe can be ROLLED—rotated during the welding —the welding process is simple. The technique is about the same as for welding plate in the flat position. Start the weld just to the RIGHT OF TOP CENTER and BETWEEN two tacks. Have a helper roll the pipe as you do the torch work.

You'll get along swell until you get back to the place where you started the weld. Then you'll need to use this special technique—

> Just before you reach the starting point, move the torch ahead and preheat the cold weld. Then go back and pick up your puddle and carry it into the preheated starting point. Fusion and penetration must be good or the weld will leak or lack strength.

FIXED POSITION PIPE WELDS

You should be able to make a good rolled weld the first time. But you may have a little trouble with your first weld on a pipe that cannot be rolled during welding. An

entirely different technique is involved. Consider first a weld made on a fixed horizontal pipe.

Space and locate the required four tacks as shown in figure 80. Start welding at point *A* and weld up the right side until you reach point *B*. Then return to point *A* and preheat the beginning of the weld. Then weld up the left side of the pipe to *B*. Preheat the cold metal at *B* to insure good fusion and penetration.

As you weld you will have to change the angle of the torch CONTINUOUSLY. On each of the two welds you will start out with overhead welding, gradually switch to vertical welding, and finish up on top with the flat position technique. That's why the angle of the torch must keep changing.

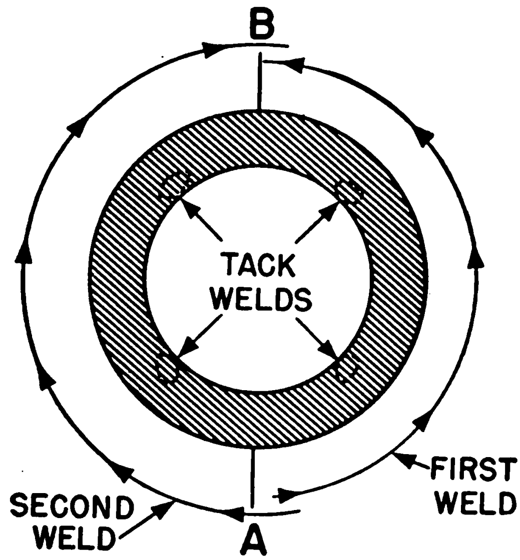


Figure 80.—Weld on horizontal fixed pipe.

For a weld on vertical pipe (figure 81) you'll have to exert your greatest skill. This is one of the Metalsmith's toughest welding jobs, because the direction of welding is HORIZONTAL.

The pipe should be beveled 30° instead of the usual 37½° or more. Tack weld the pipe in four places. Hold the torch so that the flame points slightly upward. USE THE BACKHAND METHOD. Start AT a tack and carry the weld completely around the pipe.

When you have mastered the horizontal weld on a vertical pipe, you can start calling yourself a welder. After that you won't have to worry about passing welding tests for Metalsmith Third and Second Class ratings.

WELDING HIGH-CARBON AND TOOL STEEL

As high carbon steel and tool steel are difficult to weld satisfactorily, a special technique is used. Melt and fuze the filler rod DROP-BY-DROP. Don't use a full puddle. Use a minimum of heat. The main idea is to fuse the parts together without destroying the original properties of the welded parts.

Use a carburizing flame. No flux is necessary. Sparking of the weld metal indicates overheating. Avoid it. Bubbles indicate the formation of carbon-dioxide gas. You can avoid bubbles by constantly checking your flame adjustment.

Tool steel containing more than 0.80 percent carbon should be slowly preheated to about 1000°F. Heavy pieces

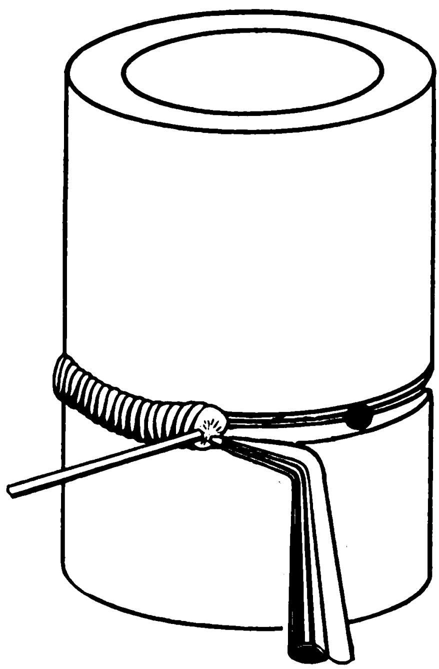


Figure 81.—Weld on vertical fixed pipe.

may be V-ed. If heat treatment of the welded part is required, the heat treating is done AFTER the weld is made.

NOTE—Tool steel is often brazed or silver-soldered. The lower temperatures required do not damage the metal as much as the high temperatures required for welding.

WELDING STEEL CASTINGS

Most steel castings contain less than 0.35 percent carbon, and can be welded with the same technique, torch

tip, flame and rod used for similar thicknesses of steel plate.

Steel castings are ordinarily arc-welded because the extended heating required for gas-welding takes a lot of time and is injurious to the metal.

WELDING CORROSION-RESISTING STEEL

Sheets of corrosion-resisting steel are often gas-welded. Thin sheets are usually flanged and welded without the addition of filler rod. Filler rods for thicker sections should contain columbium or titanium. These elements help prevent undesirable changes in the original properties of the base metal.

Adjust your flame so that it is slightly CARBURIZING. An oxidizing flame will ruin the weld. Try to complete the weld with one continuous pass—avoid making it in short sections. When you are finishing the weld, withdraw the torch SLOWLY to prevent the formation of gas pockets.

A special flux must be used. Mix this flux with water to form a thin paste. Brush the mixture on and under the joint. Allow the flux to dry for several minutes before you start to weld.

Brazing with silver solder is preferred for lap joints on extremely thin sheets because distortion is not so great at the lower temperatures used for brazing. Corrosion-resisting steel expands and contracts about 50 percent more than mild steel, but its heat conduction rate is much slower. That's why you can use a smaller torch tip for corrosion-resisting steel than for ordinary carbon steel.

WELDING CAST IRON

You may be called upon to weld cracks and breaks in cast iron (gray iron) castings. The welding procedure is somewhat different than for steel. The broken surfaces must be thoroughly cleaned and V-beveled to an angle of 90° (45° on each side). Heavy sections should be double-beveled (beveled from both sides). Form the bevels by chipping or grinding. Do NOT use the cutting torch on cast iron.

Arrange the casting so that you can make a weld in the flat position. Vertical and horizontal welds are impractical and difficult—almost impossible. Use a neutral flame

and a tip one size larger than you use for the same thickness of steel. Use a cast iron welding rod.

Preheat the casting before welding or the unequal expansion caused by the heat of welding will cause more breaks. In order to preheat the casting properly, you may have to build a temporary furnace of fire bricks around the casting. Preheat slowly and uniformly. Avoid air drafts. Cover the top of the furnace with asbestos sheets.

When the casting reaches a dull red heat, remove the asbestos from the area where the weld is to be made. Make the weld with a RIPPLE technique by fusing together one puddle after another.

Keep the end of the welding rod hot—just about ready to melt. If you dip a cold rod in the hot puddle it will form a hard spot in the finished weld.

Make sure you have penetration to the bottom of the V. Try to complete the weld without stopping. Puddling with the cast iron rod helps to remove undesirable oxides, as does the use of a good flux. But use only enough flux to keep the puddle surface clean and shiny.

Cast iron becomes extremely fluid when melted. If it gets too hot, the molten metal will run like water and you won't be able to control the weld metal. When you think the metal is getting too hot, lift the torch for an instant to lower the temperature. However, the best practice is to avoid too much heat in the first place. When you lift the torch, oxides form rapidly on the metal.

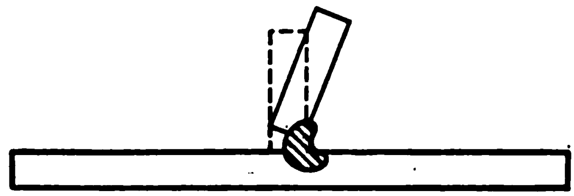
Welded castings must be cooled SLOWLY, some for as long as 24 to 48 hours. When you're through welding, heat the casting to 1600°F. and cool it in the same furnace you used for preheating. Small castings may be covered with asbestos paper or buried in warm, dry sand. If the cooling is too fast, the casting may crack. It's certain to have internal stresses. Fast cooling also makes the weld metal extremely hard, brittle, and weak.

EXPANSION AND CONTRACTION

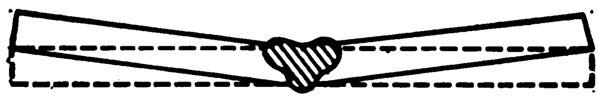
You've probably found out by now that when a metal is heated, its dimensions increase, and that when the metal cools, they decrease.

The high temperatures necessary for welding cause a lot of trouble in the form of warping, knuckling, and

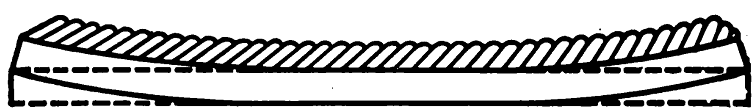
other forms of distortion. Figure 82 shows how distortion may occur if it is not allowed for or controlled.



VERTICAL WORK PULLED OFF CENTER



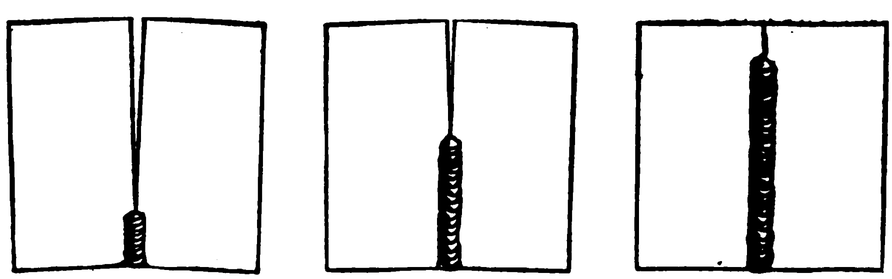
FLAT WORK PULLED OUT OF LINE



FLAT WORK IS DRAWN INTO CURVE

Figure 82.—Distortion caused by heating and cooling.

Tack welding helps a lot in preventing undue distortion. You'll usually tack-weld sheet metal joints at frequent intervals. Most joints can be alined and held in place with



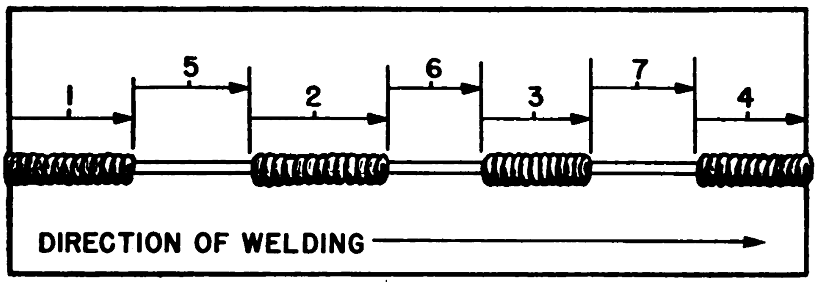
(A) (B) (C)

Figure 83.—Allowance for straight butt weld.

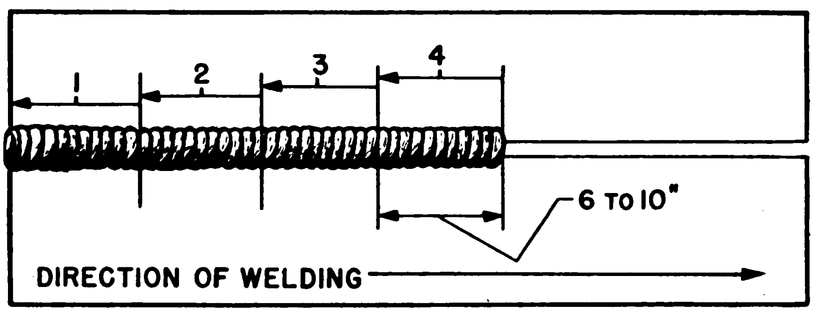
pieces of angle iron and ordinary C-clamps. Special clamps and jigs may have to be made up for some jobs.

On a straight, butt-welded seam, you can make an allowance for distortion by spacing the edges as shown in figure 83. The usual allowance for steel is ¼ inch per lineal

(running) foot. As the weld metal cools behind the puddle, it will contract and pull the edges into the proper position.



STAGGER WELDING



BACKSTEP WELDING

Figure 84.—Stagger and backstep welding.

A wedge may be used to keep a long joint open for welding. Keep the wedge 15 to 20 inches ahead of the weld.

INTERNAL STRESSES

In addition to simple expansion and contraction, the heat of welding may set up internal strains and stresses. These may be powerful enough to cause a break in the weld or in a weak part of the structure. Even if no break occurs, there is always a certain amount of internal stress left as a result of the welding heat. This condition, known as RESIDUAL INTERNAL STRESS, cannot be prevented entirely. But—you can control and decrease it by BACKSTEP and STAGGER WELDING. These methods are shown in figure 84. They prevent overheating and allow the metal to cool more uniformly.

Uniform preheating and postheating also help to minimize the internal stresses. And the stresses can be completely removed from a welded structure by the proper

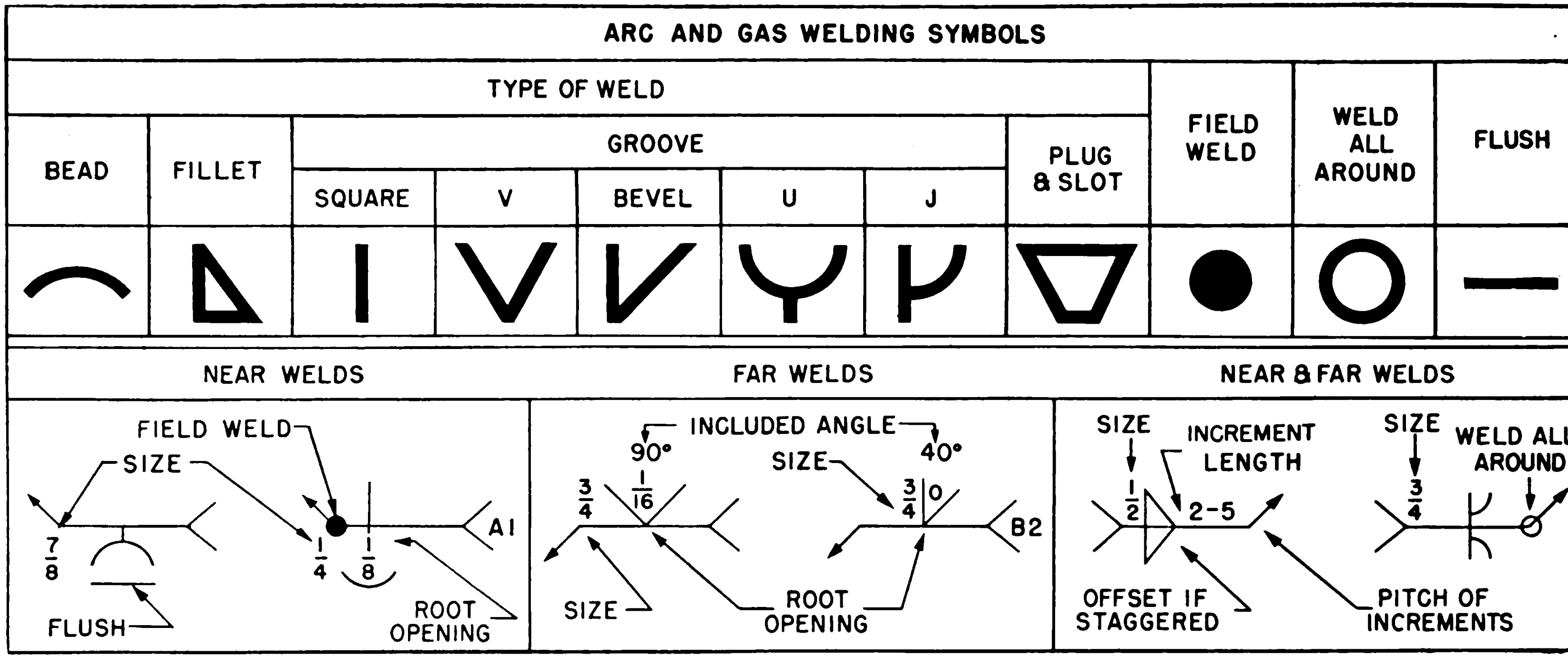


Figure 85.—Basic welding symbols.

annealing and normalizing processes. These processes are discussed in Chapter 13.

AVOID quenching welded joints in water. Any fast cooling from the welding heat will cause unnecessary distortion and internal stresses.

WELDING SYMBOLS

Special welding symbols are used on blueprints and sketches to show the kinds of welds to be used. These symbols are standardized by BuShips and apply to both gas and arc welding. You're expected to know them so you can make the welds specified on blueprints. Study the basic symbols of figure 85.

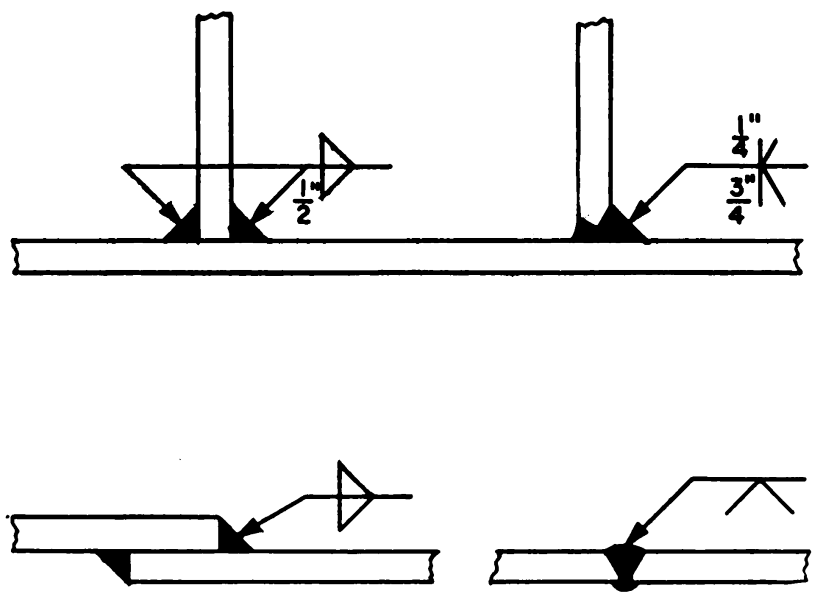


Figure 86.—Welds with symbols.

The symbols are placed on horizontal lines in open spaces on the drawing. Arrowhead-tipped lines indicate the location of the welds. The line on which the symbol is drawn is known as the REFERENCE LINE. If the weld is on the arrow side of a joint, the symbol is placed on the UNDER side of the reference line. If the weld is to be made opposite the arrow, the symbol is placed ABOVE the reference line.

Sample welds, with weld symbols, are shown in figure 86. Study these symbols and the welds they represent. They are the ones you'll meet up with most often.

By using the guide in figure 87, you can figure out the

meaning of any unfamiliar symbol. This guide shows the relative location of all symbols that may be used to describe a weld.

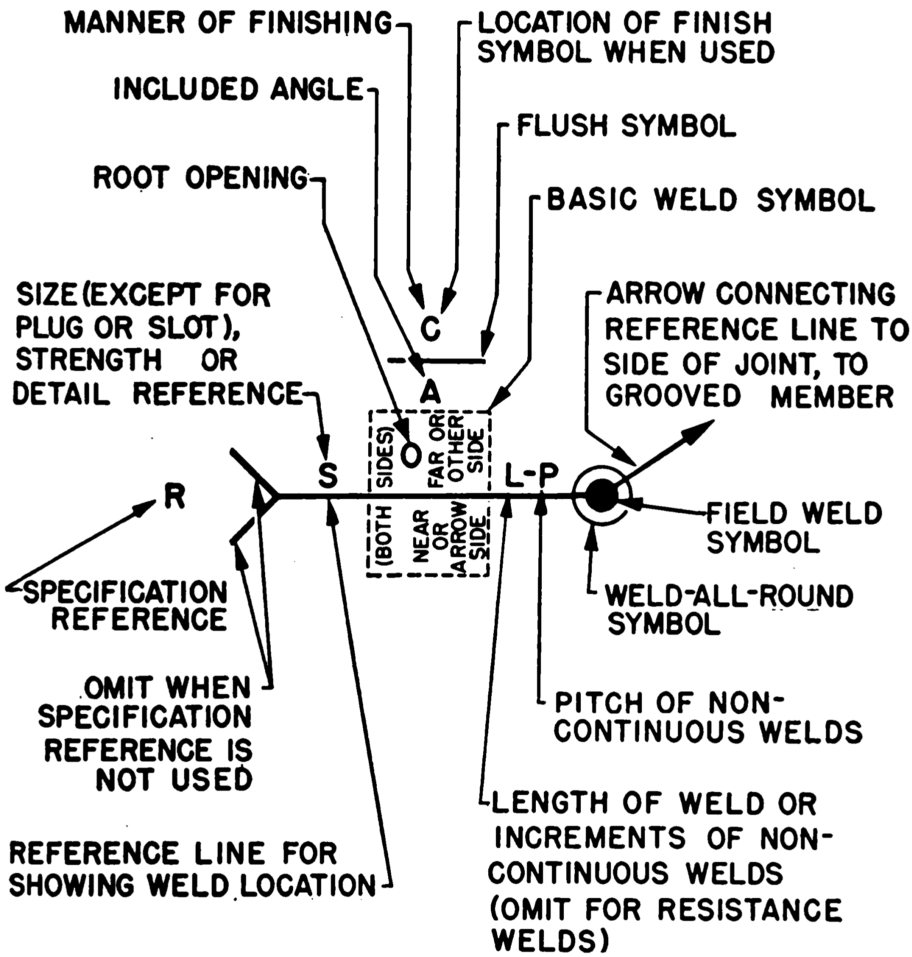


Figure 87.—Guide for reading symbols.

THE ABC'S OF GAS WELDING

The ABC's of gas welding are simple and easy to remember. Here they are—

ALWAYS
BE
CAREFUL

CHAPTER 5

OXYACETYLENE CUTTING

IT'S AMAZING

The oxyacetylene cutting torch is one of the most amazing tools a Metalsmith uses. With it you can cut through inches of the toughest steel in a remarkably short time. It's such a valuable tool that it rates top priority in a damage control locker. And—on top of all that—it's easy to use.

The cutting torch works well because it takes advantage of a CHEMICAL REACTION that occurs when pure oxygen comes in contact with red-hot steel. When the stream of oxygen comes in contact with the hot steel, the steel actually BURNS.

Technically speaking, the steel is changed to iron-oxide at a terrific rate of speed. The oxide then is blown out or flows out as slag. About 75 percent of the metal is completely consumed—burned up. The secret of the whole process is that iron-oxide melts at a much lower temperature than does steel.

The cutting action won't take place, however, unless the steel is PREHEATED along the line of cut AHEAD of the cutting blast. If you direct a stream of oxygen at a piece of cold steel you won't observe any change in the steel. But,

when you preheat that same steel to 1600–1800°F. and then open up the oxygen blast, you'll get plenty of fireworks and a hole right through the steel.

There is practically no limit to the thickness of steel plate that can be cut by the oxyacetylene method. The limit for a general purpose torch—the kind you'll have—is about 18 inches of carbon steel. Most of the alloy steels can also be cut. Cast iron can be cut, but it's hard to control the cut.

DO NOT USE THE CUTTING TORCH ON NON-FERROUS METALS.

THE CUTTING TORCH

The special torch used for cutting (figure 88) performs two functions. First, it provides oxygen-acetylene flames which preheat the steel to be cut. Second, it furnishes a blast or stream of pure oxygen which oxidizes and burns out the metal.

The preheating flame is about the same as a welding flame. The difference is that the cutting torch has several orifices (usually four) which provide preheating flames. If only one flame were provided, the heat would be insufficient and it would be difficult to change the direction of the cut. That's because the steel MUST BE ADEQUATELY PREHEATED AHEAD OF THE CUT.

A set of tips (four or five) is usually provided with each cutting torch. A special nut screws into the torch head to clamp the tip in place. Tips can be changed quickly. It's up to you to decide which tip to use. Your selection should be based mostly on the thickness of the metal. If the metal is scaly or rusty, you may have to use a larger tip than you would ordinarily use. Metal cuts best when it is clean.

CUTTING ATTACHMENTS are often used with the torches used for welding. One of these is shown in figure 89.

The cutting torch is connected to the oxygen and acetylene hoses in the same way that a welding torch is connected. The preheating flames are lighted just like the flame of the welding torch. And the same SAFETY PRECAUTIONS must be observed, so

DON'T USE OIL ON THE EQUIPMENT

and

DON'T USE THE EQUIPMENT WHERE THERE IS OIL.

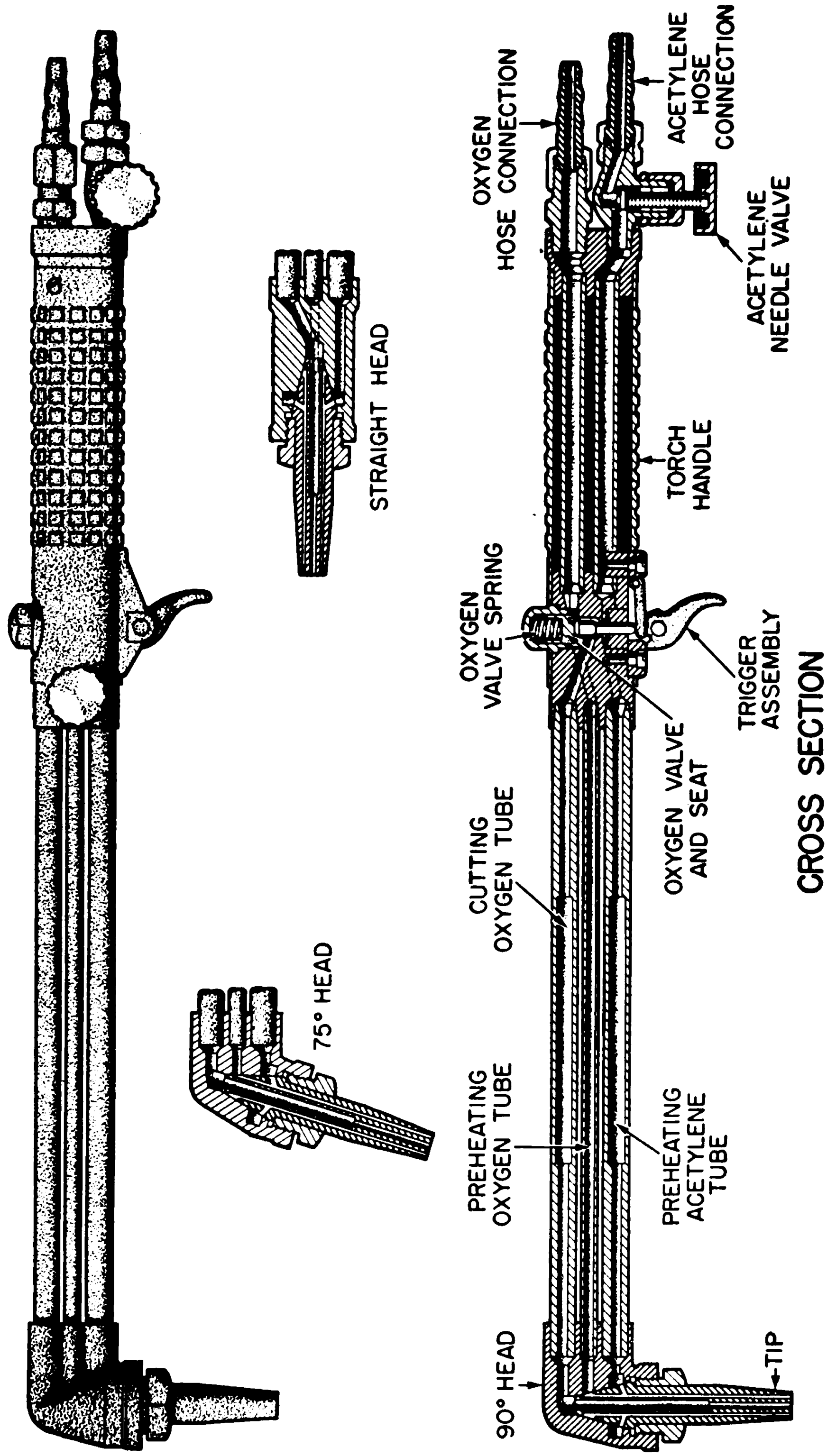


Figure 88.—One type of cutting torch.

The CUTTING TORCH has two needle valves which regulate the oxygen and acetylene mixture used to feed the preheating flame. These are similar to the needle valves

of a welding torch. Another valve, controlled by a trigger or lever mounted on the handle, controls the stream of oxygen used for the actual cutting.

Do not use the cutting torch near ANY material that might catch fire from the flame, sparks, or hot metal.

Before you light the torch, CHECK ALL ADJACENT COMPARTMENTS—ABOVE, BELOW, AND ON ALL SIDES—particularly when you are working away from the shop. Always post a fire watch with a CO_2 extinguisher. If you're working on a bulkhead, POST FIRE WATCHES ON BOTH SIDES. Always note the location of fire plugs before you start to work.

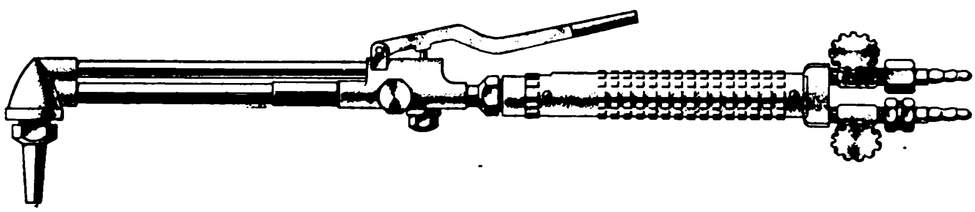


Figure 89.—Cutting attachment for a welding torch.

It is extremely important that you take all safety precautions possible. Plenty of damage has been caused by careless handling of cutting and welding equipment. Remember the NORMANDIE fire? It was started by an oxyacetylene flame. So was a recent shipyard fire in Australia which caused damage of $1,500,000.

PRELIMINARY PROCEDURE FOR CUTTING

Select and install the desired tip and connect the torch to the hoses. Follow the directions of the torch manufacturer in selecting the tip and adjusting the oxygen and acetylene pressures.

CHECK EVERYTHING FOR SAFETY. Protect yourself by wearing your goggles and gloves. It's a good idea, too, to rig up some type of shield for your feet and legs—so the hot slag and sparks won't be able to reach them.

Pick up the torch in your right hand and hold it in such a manner that you have FULL CONTROL of the cutting-oxygen lever or trigger. Open the acetylene needle-valve and light the flame with the sparklighter. Open the oxygen for the preheating flame and make an approximate adjustment of the preheating flame. Then open the cutting-oxygen valve and quickly adjust the preheating flame to

NEUTRAL. Release the cutting-oxygen valve as soon as the adjustment is made. Now the torch is ready to use.

STARTING THE CUT

With the preheating flame burning and the cutting oxygen OFF, preheat a spot on the layout line near one edge of the metal. Hold the torch at an angle of 45°, with the flame cone tips about 1/16 inch from the surface. As soon as the spot becomes RED-HOT, gradually open the cutting-oxygen valve. The cutting action will begin almost immediately and the sparks will start to fly from the under side of the cut. (Note how the torch is held by the workman in figure 90).

As soon as the cut is started, move the torch SLOWLY along the cutting mark or guide. The angle of the tip is increased until it is about perpendicular (90°) to the surface of the metal. As you move along, keep an eye on the cut so you can tell how it is progressing. Make torch adjustments if necessary.

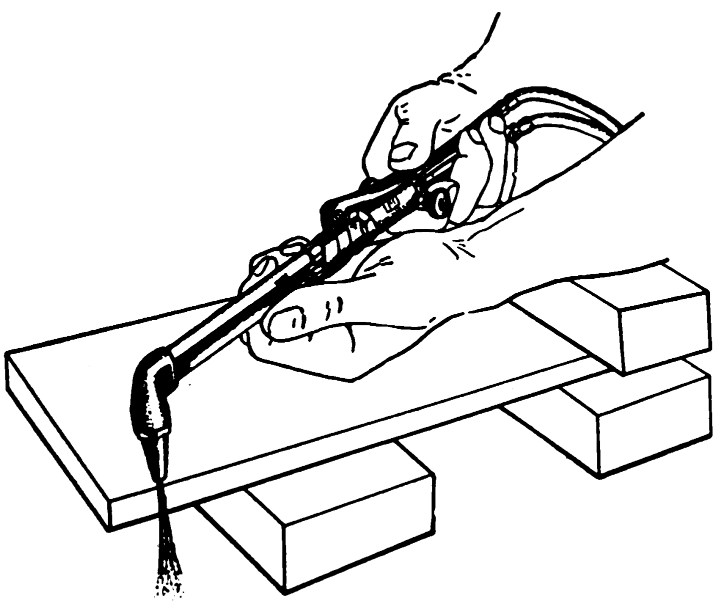


Figure 90.—Starting the cut.

You'll need to move along at just the right speed—not too slow and not too fast. If you go TOO SLOW, the preheating flame will melt the edges along the cut. It may even weld them back together at the surface. If you go TOO FAST, the oxygen will not penetrate completely

through the metal and the cut will be incomplete. In that case you'll have to close the cutting-oxygen valve and go back, preheat, and make a new start at the beginning of the partially cut area.

Try to make the cut as smooth as you can. Anyone who can light the torch can cut steel after a fashion, but it takes a GOOD workman to get a smooth cut every time. If the cut isn't perfect, check up on these points—

PREHEATING FLAMES—if too short, the cut will have a gouged appearance at the bottom. If too long, the top edge of the cut will be fused.

OXYGEN PRESSURE—if too low, the top edges will be melted. If too high, the cut will be extremely rough and irregular.

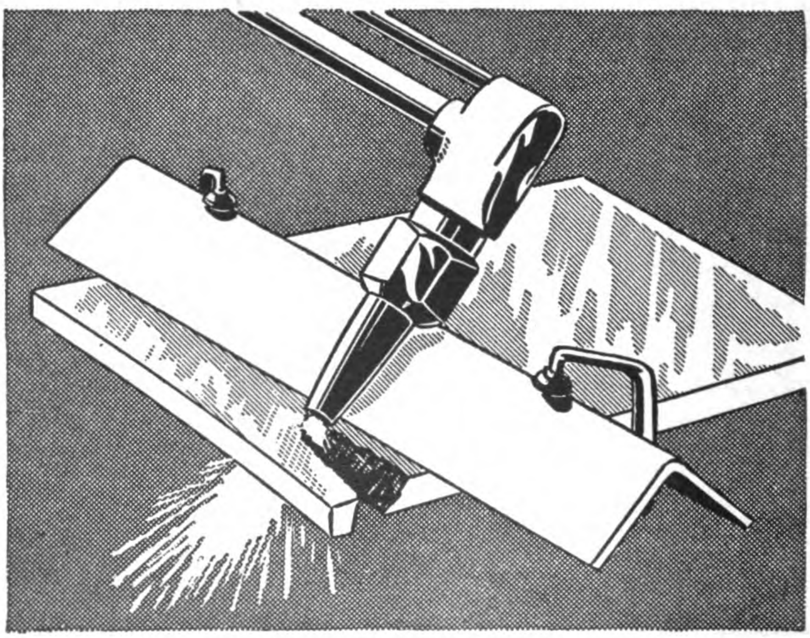


Figure 91.—Bevel cutting.

CUTTING SPEED—if too slow, the "drag" lines are irregular. If too fast, the drag lines are rough and form sweeping curves.

NOTE—Drag lines are the marks left on a cut edge. A good cut shows smooth, vertical, uniform marks which are continuous from the top surface to the bottom surface.

CUTTING BEVELS FOR WELDING

To make a BEVEL CUT of 45 degrees in 1-inch steel, the flame must actually cut through 1.4 inches of metal! Con-

sider this when you are selecting the tip and adjusting the valves. You'll have to use MORE PRESSURE and LESS SPEED for the bevel cut than for a straight cut.

When you've going to do bevel cutting, adjust the tip so that the preheating orifices are lined up for efficient preheating. A piece of 1-inch angle iron, clamped with the angle UP, makes an excellent guide for beveling straight edges. Pull the torch along this guide as shown in figure 91.

PIPE CUTTING AND BEVELING

When you're cutting off a piece of pipe, keep the torch pointed toward the CENTERLINE of the pipe. Start the cut at the top and cut down one side. Then begin at the top again and cut down the other side, finishing at the bottom of the pipe. The process is diagrammed in figure 92.

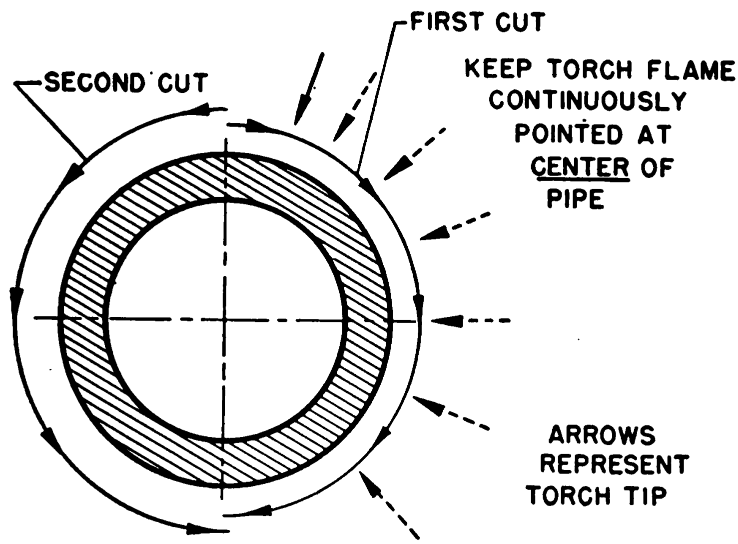


Figure 92.—Pipe cutting.

Pipe beveling with the cutting torch requires a steady hand to get a good bevel—one that is smooth and true. Don't try to cut and bevel a heavy pipe in one trip. Cut the pipe off square first, then bevel it. This makes a cleaner and better job.

Check the alinement of your torch tip preheating orifices before you start to work on pipe. Arrange these orifices in a pattern that will be most efficient for preheating AHEAD of the cut.

PIERCING A HOLE

You can easily pierce a small hole through steel plate. Lay the plate on two fire bricks in such a manner that the flame won't be obstructed when it burns through. Then preheat the hole location with the tips of the inner cones of the preheating flames held about ¼ inch above the surface of the plate.

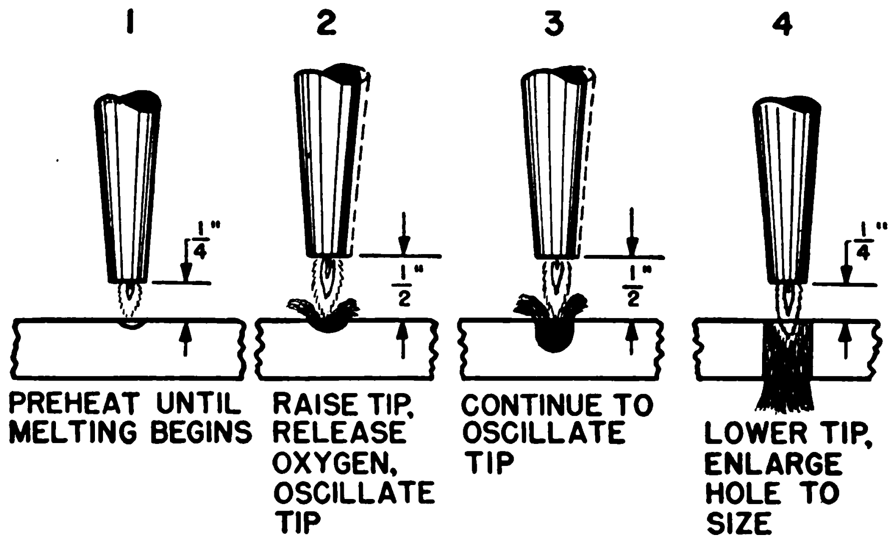


Figure 93.—Piercing a hole.

When the steel starts to melt gradually raise the tip and open the cutting-oxygen valve. The inner cone tip should now be about ½ inch above the surface of the plate. As the torch is being raised and the cutting valve is being opened, start rotating the tip with a spiral motion. This will cause the melted slag to be blown out of the hole. The hot slag may fly around some—be sure your goggles are well-fitted to your eyes and face. Avoid having your head directly above the cut.

After you get the hole completely through the metal, lower the inner cone tips of the preheating flames to the normal distance and enlarge the cut to the desired size with the normal cutting method.

CLEANING THE TIP

The blowing action of the oxygen blast tends to "bounce" the molten metal and slag from the cut back up to the torch tip. So—you'll have to clean the tip orifices often. Use the proper size tip-cleaning drills for this.

If the end of the tip becomes rough and pitted and the orifices become OVERSIZE (bell-mouthed), you can recondition the tip in this manner—

> Place a piece of emery cloth, grit side up, on a flat surface. Hold the tip perpendicular to the emery cloth and rub it back and forth just enough to true the surface and bring the orifices back to their original diameter.

After you clean the tip, test it by lighting and observing the preheating flames. If the flames are too short, the gas passages are partially blocked. If the preheating flames snap out when the valves are shut, the orifices are still bell-mouthed and the tip needs further working down to bring them back to their original size.

If the tip SEAT is dirty and scaly so that it fits the torch head imperfectly, heat it to a dull red and quench it in water. This loosens the scale and dirt enough so that you can easily rub it off with a cloth.

EMERGENCY CUTTING

Ordinarily the responsibility for making an emergency cut won't be left up to you. You'll make the cut ONLY WHEN ORDERED TO DO SO BY A SUPERIOR OFFICER OR PETTY OFFICER.

The cutting torch is used sometimes as a LAST RESORT to cut open doors and other closures which have become jammed shut. Try all other methods before you use the torch. And don't use the torch UNTIL YOU KNOW WHAT IS ON THE OTHER SIDE OF THE BULKHEAD OR DECK. BEWARE OF OILS AND GASES. Use an explosimeter to test the air.

When you make an emergency cut, be sure that you station fire-fighters, equipped with CO_2 extinguishers, where they can immediately quench any fire that might be started.

If you are cutting through a bulkhead to free trapped personnel, cut the hole only large enough for a man to crawl through. If gear must be carried through, the hole can be enlarged easily. Avoid cutting through structural members.

Portable oxyacetylene cutting outfits are kept in damage control lockers. These outfits are arranged so that they can be used on a minute's notice.

CHAPTER 6

BRAZING AND SILVER-SOLDERING

WHAT IS BRAZING?

BRAZING is a method of joining metals together, WITHOUT FUSION, by means of molten alloys whose melting points are above 1000°F., but well below the melting points of the metals being joined.

Except for the higher temperatures required, brazing is much the same as soft soldering. In fact, brazing is sometimes known as "hard soldering." The brazed joint is far better and much stronger than the soft-soldered joint and can withstand much higher temperatures.

Brazed joints are almost as strong as welded joints. Brazing is even preferred for many joints in cast iron, non-ferrous metals, tool steel, and malleable iron. One advantage of the brazing of joints is that the heat required is not sufficient to cause serious damage to the properties of the joined metals. This is a big advantage when you're working with alloy steels and tool steels.

Three general types of filler alloy are used. BRASS RODS or SPELTER (small grains of brass) may be used as filler metal for brazing copper and brass pipes, tubes, sheets, and fittings. Brass is also used to join unlike metals—brass to steel, brass to cast iron, or cast iron to steel. General repair work on machines and castings is usually

done with brass rod. And it is the best filler metal for brazing galvanized sheets and pipe.

SILVER ALLOY SOLDER is used extensively in modern warship construction for joining non-ferrous metals. You can use silver solder on pipes and tubes when the work is done on location—without dismantling the system. Silver solder is much easier to use and control than brass when the brazing must be done in a tight spot, such as near the overhead or near a bulkhead. Silver solder is seldom used with iron but is used extensively on steel piping and it may be used on small sections of tool steel. The use of silver alloys for joining metals is known as EITHER SILVER-SOLDERING or SILVER-BRAZING.

BRONZE ROD is used to build up worn gear teeth, bearing surfaces, and shafts, and for joining metal parts which are to be subjected to high temperatures. When properly applied, all three types of alloys used for filler make strong, shock-resistant and vibration-resistant joints.

GET IT READY

Parts to be brazed must be THOROUGHLY CLEANED. Remove ALL dirt and discoloration caused by oxidation. If the parts are covered with grease or oil, remove them with heat. If the parts are rusty or otherwise corroded, clean them by filing, sanding, grinding, or sandblasting. Or—scratch the surface with a wire brush until it has a bright shine.

DO NOT ATTEMPT TO BRAZE DIRTY METAL. You may get a weak, leaky joint that is full of pin holes.

When possible, brazing is done in the shop on a welding bench. No matter where you're working, arrange your work so that you have no air drafts on it. Pipes and tubes should be partially blocked off—else they will work as a chimney or stack and cause a draft, which will carry away a large part of your heat. A piece of light sheet metal, or sheet asbestos, may be placed over the end of a pipe to help prevent such a draft.

Use flux liberally during the brazing operation. It may be mixed with water and brushed on the surfaces of the parts to be joined, or the rod may be heated and dipped into either powdered or paste flux.

BRAZING FLUX FOR BRASS ROD

A flux of some sort is always used to increase the flow of the brazing alloy and to increase its "stickability." The flux acts to prevent the oxidation of the metal surfaces and to remove oxides already present. It brings the brazing filler into intimate contact with the metals being joined, and causes the filler to penetrate the pores of the metal—thus forming a strong bond.

BORAX is used as a flux for high-temperature brazing (1350° to 1800°F.) when brass filler is being used. Up to a certain point, heat causes borax to swell, especially when large amounts of borax are used. This is a natural action. When the temperature reaches about 1300°F., the borax stops swelling, melts down, and becomes a sticky liquid which clings to the metal. It is at this stage that the borax is most effective in dissolving the oxides. When the temperature of the surface reaches the melting point of the filler metal, the brass rod is touched to the joint. The rod melts and flows into the joint and into the pores of the metal, which have been kept clean and open by the flux.

Borax in the lump form should be kept on hand and powdered as required. If commercially powdered borax is used, it should be kept in sealed glass jars. Borax powder may be mixed with water and used to coat closed joints—as, for example, when a copper pipe is to be brazed to a cast iron flange. Ordinarily the flux is applied by heating the rod and dipping it in the borax powder. Sufficient flux will stick to the hot rod.

Commercial fluxes are used in the same way as borax because they are usually made mostly of borax.

HEATING HINTS

When heavy and thin metal sections must be brazed together, you'll have to be careful to avoid overheating the thinner part. A good example is the brazing of thin copper tubing to a heavy cast fitting. If the same amount of heat were applied to the tubing as to the casting, the tubing would be overheated and probably burned. Therefore, most of the heat must be directed at the heavier part.

Most of your brazing will be done with the heat supplied by an acetylene welding torch. Select a torch tip to suit the kind of work you are doing. You'll ordinarily use

sizes 4, 5, and 6 for brazing sheet stock. The table in figure 94 below may be used as a general guide for pipe work.

SUGGESTED TORCH TIP SIZES FOR BRAZING AND SILVER-SOLDERING PIPE

Pipe Size	Tip No.	Oxy. Pres.	Acety. Pres.
¼ and ⅜	4	8	6
½ to 2½	6	12	10
3	8	12	10
4, 4½, 5	8	15	12
6 and 8	9	20	15
10	10	20	15

Figure 94.—Tip sizes for brazing pipe.

When you need to silver solder extremely small pieces, you'll do well to select a soft flame, lead-burning torch.

The torch flame should be slightly oxidizing—have a slight excess of oxygen. Keep the INNER CONE of the flame from ¼″ to ½″ AWAY from the metal. PLAY THE FLAME over the surface with a circular, sweeping motion, so that you obtain UNIFORM heating of the parts to be joined. The flame should be "soft" so that it won't blow or boil the molten filler metal.

Bring up the temperature of the parts until the flux on them is melted. Continue heating until the parts to be joined are hot enough to melt the filler rod. THE FILLER SHOULD BE MELTED BY THE HEAT OF THE JOINT, NOT BY THE FLAME. It should flow like water wherever the flux has been applied. Avoid overheating—use just enough heat to get the parts of the joint hot enough to melt and flow the filler metal.

You'll find that the toughest part of brazing and silver-soldering is HEAT CONTROL—manipulation of the torch. And you can't learn that skill wholly from books. The best way to learn to control the heat is to get PLENTY OF PRACTICE. It will also help to watch an expert braze up a few joints.

Heavy parts and large areas must be PREHEATED for best brazing results. Preheating may be done with a forge, furnace, oil-burning torch, gasoline torch, or with another welding torch. Use oil-burning equipment when you can—it's much more economical than acetylene.

POSTHEATING

You also need COOLING CONTROL. Slow and uniform cooling is essential for a good joint. You can control and equalize the rate of cooling by POSTHEATING—heating after the joint is completely brazed. The lightest or thinnest metal should receive most of the postheating because it naturally cools faster than a heavy section. In other words, maintain a uniform heat throughout the whole joint as you allow it to slowly cool.

AVOID PLACING ANY STRESS ON A BRAZED JOINT UNTIL IT HAS COOLED BELOW 500°F. The filler metal is weak—has a low tensile strength—at higher temperatures. When hot metal is weak at certain temperatures, it is said to be "hot-short."

Brazed joints may be annealed and cold-worked without damage, but SHOULD NEVER BE HOT-WORKED.

BRASS-BRAZING SHEET METAL

Lap and butt joints in sheet metal are often brazed with brass rod as a filler metal. The diameter of the rod should be about the same as the thickness of the sheet. Rods of 1/16 inch brass are usually used for brazing joints on lockers, tool boxes, ventilation ducts, and other structures made of galvanized steel. Figure 95 shows three joints suitable for brass-brazing.

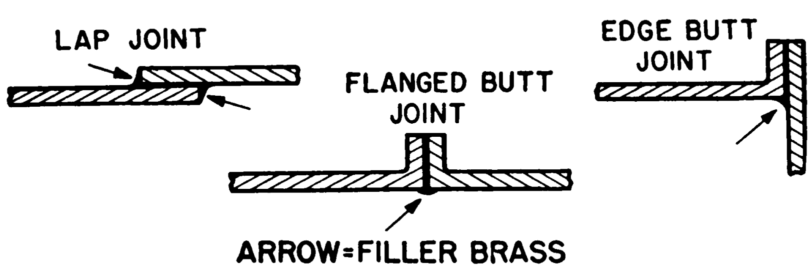


Figure 95.—Recommended joints for brass-brazing sheet metal.

Any sheet metal having a melting point above 1600°F. can be brazed with a suitable brass rod.

SILVER-SOLDERING

You may hear an old-timer say "It's not like the old Navy," and he is entirely right. For example, a lot of soft solder was formerly used on jobs where it wouldn't stand up in modern ships. Now the Navy uses silver solder for

most of those jobs. That's why it's important for you to learn to do a good job of silver-soldering.

Threaded joints and fittings have been replaced almost 100 percent by silver-soldered joints for non-ferrous piping and tubing which have been installed or replaced on modern ships.

Two important factors are responsible for the increased use of silver solder. The first is that the melting points of the various silver solders are much lower than those of brass and bronze brazing alloys. Silver solders can be used without danger of burning the joined metals. And as less heat is required, less acetylene and oxygen is used. The second important factor is that silver solder provides a more efficient method of joining metals than do brass and bronze fillers. It is easier to apply, especially in crowded locations, and yet provides a highly satisfactory joint. Silver-soldered joints also require less room or space than threaded joints.

Parts to be joined with silver-alloy solder are prepared and cleaned the same as for brass brazing. Heat application is also similar, except that lower temperatures are used for silver-soldering.

Silver solder alloys are classified into seven grades, known as O, I, II, III, IV, V, and VI. Of these seven you'll use grades III and IV the most. The Navy specification symbol for all grades is 47–S–13.

GRADE II usually comes in rectangular or square rods. It contains 15% silver, 80% copper, and 5% phosphorus. Its melting point ranges from 1185° to 1300°F. Use it to join copper-to-copper, copper-to-brass, copper-to-nickel alloys, and brass-to-brass. In other words, use it on non-ferrous metals. It's the grade you'll use most on copper and brass pipes, tubes, and sheets.

GRADE IV is composed of 50% silver, 15% copper, 18% cadmium, and 17% zinc. Its melting point ranges from 1160 to 1175°F. It flows freely when melted (about like kerosene), and is used for joining ferrous metals to ferrous metals, and ferrous metals to non-ferrous metals. It's made in wire and square rod forms.

GRADE V silver solder alloy is used for jobs that do not fit too well. It comes in an octagon-shaped rod and melts at temperatures ranging from 1180 to 1270°F. It is the only silver solder alloy which can be used satisfactorily

as a filler metal. This alloy flows sluggishly—about like molasses. Its best use is for joining non-ferrous metals to ferrous metals.

Inserts of silver solder are now being placed in the circular grooves of some pipe flanges and fittings used with copper and brass pipe. These inserts are economical, and they make strong joints because of the silver alloy is uniformly distributed over the entire area of the joint. And you'll find that they are easier to use than rod or wire filler metal—you can give all of your attention to proper heating and not have to worry about adding more filler metal. Figure 96 shows how to braze a silver-alloy-inserted fitting.

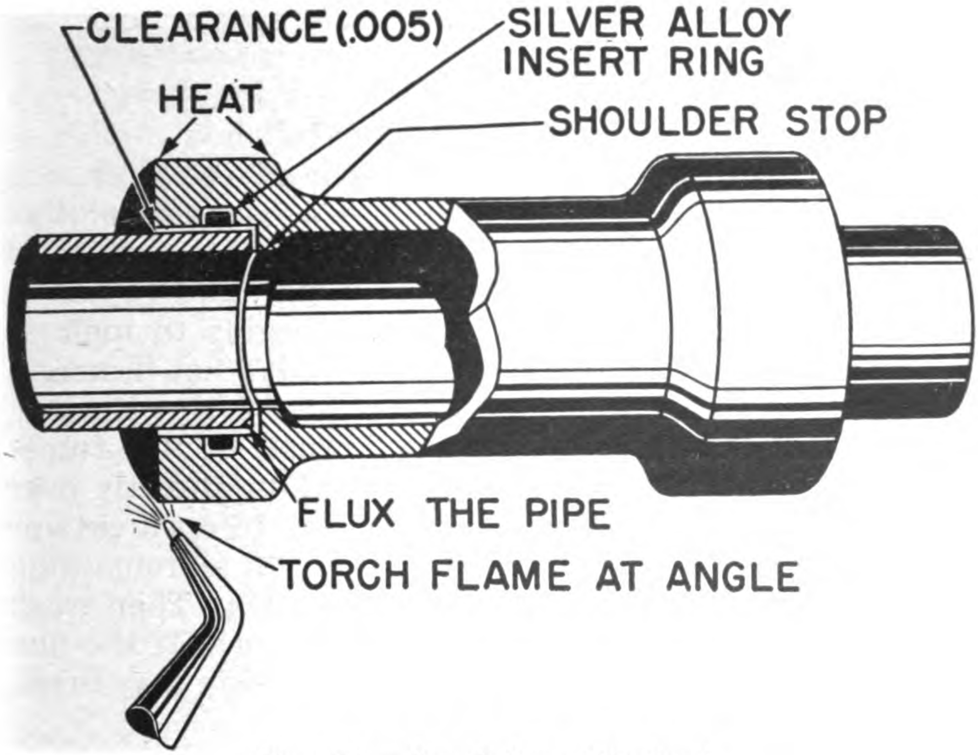


Figure 96.—Use of silver solder insert.

Silver solder SHOULD NOT BE USED on jobs that will be subjected to temperatures exceeding 450°F. when placed in service. Neither should it be used if the joined parts are to be subjected to high temperatures for annealing or bending. Except in an emergency, never use silver solder as a filler for a loose joint. If an emergency does occur, grade V silver solder may be used.

Silver solder is too expensive for use as a filler metal

for joints which do not fit closely. These loose-fitting filled joints are not as strong as close-fitting joints containing only a film of silver solder.

When you are silver-soldering a fitting to a tube, the fit of the parts should be close and snug. One-fourth to one-half inch tubing should fit with a clearance not exceeding 0.005 inches. The clearance for 3/4 inch and 1 inch tubing should not exceed 0.006 inches. No joint should have a clearance exceeding 0.010 inches. If you hold all clearances below 0.005 inch, you'll get good results.

A good fit is essential to insure a proper flow of the silver solder into the joint. You may have to work the end of the tubing to the correct size by expanding, shrinking, or peening. Some shops will have special tools for sizing the ends of tubes.

SILVER SOLDER FLUXES

While borax can be used as a flux for silver solder, you will get a superior joint if you use a commercial flux especially compounded for this purpose. One type used by the Navy is known as "Handy Flux" and comes in paste form, sealed in glass jars. It begins to melt at about 1100°. Keep the jar sealed when it's not in use.

After the surfaces to be silver-soldered are cleaned, the flux may be applied with a small brush. As the fumes from the flux are poisonous, avoid working directly over the joint. Be careful not to get any flux in open cuts or on your hands. Use warm water to clean off all remaining flux, or its residue, when the job is finished. Then wash your hands thoroughly when you're all done. If the flux or flux fumes do get into your body, your skin may break out with a bad rash.

Flux should be applied only to the area of the joint. Don't cover an unnecessarily large area as the molten silver alloy will follow the flux. Practice economy—silver solder is expensive stuff. Remember—only a small amount of silver alloy is required to produce a joint with maximum strength.

SEGMENT BRAZING FOR PIPE WORK

When you braze fittings and flanges to pipes and tubes, you can use the method shown in figure 97. This seg-

ment method is necessary for good results especially when you're working with large pipes or tubes. This system is by no means the only one you can use. Often you will have to figure out a special method to get a certain job done.

When you have to braze a pipe which runs close to a bulkhead or overhead, or both, you will have plenty of opportunity to use your ingenuity. In a case like this, it will be difficult for you to see what you are doing. One remedy is to use a miror. Have a helper hold it and adjust it while you manipulate the welding equipment. Special tip extensions, with various curved shapes, can be made of soft copper tubing. These extensions are invaluable for working in hard-to-reach places. Such an extension should be about 10″ long.

BEFORE you start to braze or silver solder ANY job decide how you are going to go about it. Work out a plan to follow, and then follow it as nearly as possible. Consult with other workmen if you are in doubt as to how to do a job.

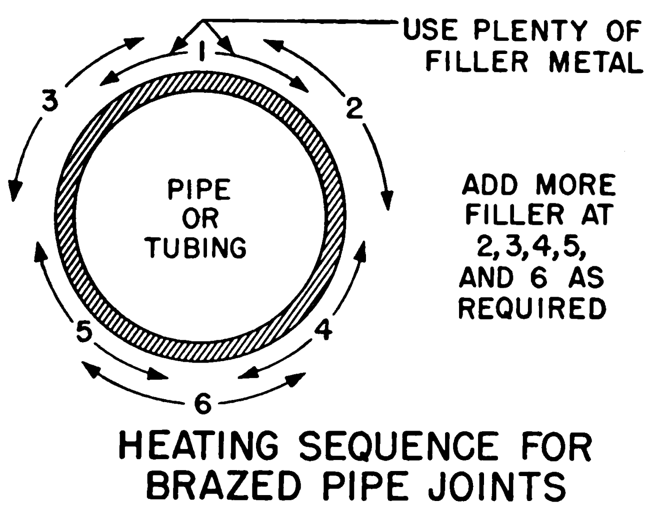


Figure 97.—Brazing horizontal pipe by segments.

BRAZING A FLANGE OR FITTING

To braze or silver-solder a flange or fitting on a copper pipe, use the following steps—

Square, smooth, and burr the end of the pipe.

Check the fit of the pipe in the flange recess. If it doesn't have the proper clearance, it's up to you to work it to the correct size.

Clean all the contacting parts. Don't touch the surfaces after you clean them—oxides will form.

Apply the flux immediately. Put the flux on the pipe only. Use only enough flux to do the job. Extra flux tends to clog the joint and prevent the spread of the filler.

Assemble the joint, and brace or support it in place.

Pre-heat the joint. Apply heat to the pipe until it becomes a bluish-black color, then apply heat to a segment of the flange collar. Use a sweeping or "wiping" motion of the flame across the collar or band. The heat will expand the collar and allow the brazing alloy to flow into the joint.

Stop heating MOMENTARILY. This allows the collar to contract and squeeze the brazing alloy evenly throughout the joint.

Heat the adjacent segments until a continuous band of brazing alloy appears at the edge of the flange. Apply additional filler as required to fill the joint.

Clean off any remaining flux and any scale that may have formed on the joint.

NOTE—For brass brazing, all flange bolt holes should be filled with asbestos or clay paste to prevent cracking of the flange. This procedure is not required for silver-soldering. POSTHEAT LARGE JOBS so that the cooling will be uniform. AVOID DRAFTS while the joint is cooling. NEVER APPLY FLAME DIRECTLY TO THE BRAZING ALLOY. Let the heated pipe and flange melt the alloy.

TIPS FOR SILVER-SOLDERING

Parts to be joined by silver-soldering must be carefully fitted and alined.

When brazing a flange to the end of a tube, make scribe marks on the tube 1″ plus the joint depth from the end of the tube. Use these reference marks to make sure that the tube is fully seated in the flange recess.

When you are using fittings with inserts, hold the torch with both hands—one hand to support the weight of the torch, the other to guide and manipulate the torch.

Protect valves with wet swabs wrapped around the

finished parts. Avoid directing flame at the working parts of a valve.

Copper-nickel must be heated carefully due to its low heat conductivity. Therefore, use less heat but more flux. Apply the flux liberally. If you're silver-soldering a tube, flux the tube end up to the scribe mark. The extra flux prevents oxidation of the copper-nickel.

When you start to heat a joint, play the flame on the tubing with a rotary or zigzag motion. When the flux melts, transfer the flame to the band or collar of the flange and use a "wiping" motion back and forth along the joint. Work a 3-inch section at one time. Allow each section to cool slightly before starting another section.

Bosses are easily silver-soldered to the topside of a tube. Just clean the surfaces, flux the edge of the boss ONLY, then apply the heat to the outside of the joint and the silver alloy to the inside.

If a boss must be placed on the UNDERSIDE of a pipe or tube just follow this procedure—

Clean and fit contacting parts.

Flux and "tin" the edge of the boss with a heavy layer of silver alloy.

Clean the tinned edge thoroughly.

Flux the tinned edge of the boss and the surface of the tubing.

Apply constant pressure to hold the boss in place.

Apply heat with a wiping motion of the torch to sweat the boss in place.

Maintain constant pressure on the boss until the joint cools.

USE THEM AGAIN

Brass-brazed or silver-soldered flanges and fittings may be reclaimed and reused. To remove a brass-brazed pipe from a flange collar, just crimp the end of the pipe with a dull cold chisel. This is necessary because the end of the pipe is usually peened. Then heat the collar uniformly until the pipe can be pulled loose. Do not quench the flange in water until it has cooled to a black heat.

DO NOT HAMMER ON THE FLANGE.

Silver-brazed flanges are removed by heat alone be-

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cause they are not peened. After the pipe has been removed, and while the flange is still hot, the remaining particles of silver alloy may be removed with a wire brush.

A temporary furnace, made with fire brick, can be built around the flange to speed and equalize the heating. Do not tap or pound or otherwise force the flange.

BLOW IT OUT

Any time you are brazing or silver-soldering, get all the fresh air you can. You can't get too much ventilation. FLUX FUMES ARE PLENTY DANGEROUS. A few good lungfuls and you'll wonder who "lowered the boom" on you.

Brass, as you know, contains a lot of zinc. ZINC FUMES ARE POISONOUS—DEADLY POISONOUS. Even a few small whiffs will give you an all-day headache. Five of the grades of silver solder contain from 13% to 37% of zinc —and galvanized metal has a zinc coating.

So make sure you have PLENTY of ventilation. If you do much brazing, drink a lot of milk. The milk acts to counteract the poisoning caused by zinc and flux fumes.

BRONZE WELDING

When bronze rod is used as the filler material, the HEATING PROCESS is somewhat different from that used for brass and silver brazing, especially for built-up work. Preheating and fluxing are much the same as for brass brazing.

The first step after preheating is to add a THIN coating of bronze to provide a base for the metal you will add later to form the joint or the built-up section. This process is called TINNING.

After the surface is tinned, the process resembles that of making a true fusion weld. Beads may be run but they must be thin and fused to the last layer of bronze. Two beads or layers are usually sufficient; three may be used for some jobs. Cooling of the finished job must be uniform.

Shafts are often built up by bronze-welding. Then they can be machined to size. Holes which have been worn oversize can be partially filled in and then re-drilled or rebored. As it has a tensile strength of 55,000 or 60,000

psi, the added bronze, when properly applied, is just about as strong as the base metal.

When heavy ferrous parts are to be joined or repaired, V, bevel, or chamfer them in the same way as you would for a fused weld.

If you want to be a really good bronze welder, get a gear with broken teeth and practice building these teeth. You can also get some good practice by bronze-welding surveyed cracked castings of iron and steel.

CHAPTER 7

GAS-WELDING ALUMINUM

YOU'RE THE MAN

Don't be surprised if you look up from your welding bench and see someone hauling in an aluminum chair or locker to be repaired by welding. It's part of your job to weld aluminum and aluminum alloys. Most of your aluminum welding work will be done on castings, stampings, and forgings but you'll do some welding of sheet stock.

The alloys usually designated by the Navy for sheet stock are known commercially as 52S(Al–52) and 53S (Al–53). You may have occasion to weld some 2S(Al–2) and 3S(Al–3). Castings are usually 43S. Alloys 53S and 43S are heat-treatable but the heat treatment must be done AFTER welding. Chapter 14 will give you more information about kinds of aluminum.

If you have mastered the techniques of welding steel, you shouldn't have much trouble with aluminum. However, there are a number of important differences in the behavior of the two metals when they are heated.

One difference is that steel melts rather slowly so that the molten metal is easily controlled, while aluminum melts in a hurry and is not so well behaved. Heat aluminum just a little past the melting point and—WHOOSH—

it's melted and gone—dropped out—leaving a big hole staring you in the face. This is naturally disconcerting to a beginning welder, but don't let it bother you. You can easily learn the special techniques involved after you learn the whys and wherefores and get some practice on a few jobs.

SPEED COUNTS

If you have watched an expert making an aluminum weld you probably said to yourself, "How can that guy get such a perfect job when he goes so fast?" Right there is one of the secrets of good aluminum welding—SPEED. So don't be afraid to highball the job. Keep that torch flame moving. As soon as the metal melts, get the flame away by moving it ahead along the joint.

When you're welding aluminum you can't form a big puddle and then let the puddle melt the filler rod. You've got to hold the rod close to the flame so that it can melt into the molten metal. Now consider the flame.

Right off you might think that, because aluminum melts at a low temperature (about 1220°F.), you should use a torch tip smaller than one you would use for similar work on steel. Actually you need a LARGER tip for aluminum than for steel. That's because aluminum is such a good conductor of heat. The heat spreads throughout the metal instead of remaining in the weld area.

The welding flame should be NEUTRAL or have only an extremely short carburizing feather. The flame must be SOFT—not "blowy." That is, the gas mixture must be controlled with the torch needle-valves so that the mixture leaves the tip with a low velocity. The tip of the inner cone must be kept farther away from aluminum than from steel. NEVER allow the inner cone to touch the aluminum.

FILLER ROD

Your choice of the filler metal depends on the kind of aluminum alloy you're welding. If the base metal is 2S or 3S, the rod should be of the same composition as the base metal. You can even cut off strips of the base metal and use them as welding rods.

If the base metal is 52S or 53S, you can use rods made

of the same material or rods of 43S containing 5% silicon. The 43S rod is also used on aluminum alloy castings.

FLUX

Always use a flux when welding aluminum. The flux comes in powder form and is mixed with water to form a paste. Mix only what you require immediately—flux mixed today is NO GOOD tomorrow. Brush the flux on the rod just before you are ready to weld. If you're welding heavy sections, coat both rod and base metal.

ALUMINUM OXIDE is always present on the surface of aluminum. The melting point of this oxide is so high that it cannot be melted with the torch flame without destroying the metal. The flux melts at a low temperature and floats away the unmelted oxide.

The flux cannot work efficiently unless you have the joint CLEAN. Joints in aluminum may be cleaned with sandpaper or emery cloth, or by filing or grinding. You can prevent aluminum from clogging a grinding wheel by filling the surface pores of the wheel with beeswax.

JUDGING TEMPERATURES

Because heat control is so important, you must use some method of determining the temperature at which the metal is ready to be welded. You can't depend on the heat color because of the low melting point of aluminum. Here are three methods used by experienced welders. Take your choice.

1. Start preheating the aluminum. When it begins to get hot, rub a pine stick across the heated portion. At first you won't observe any change in the metal but when the temperature reaches 700–800° F. you will see a mark where the pine has been rubbed. Slip your goggles up while you're testing. Continue heating and again rub the stick across the metal. As the temperature of the aluminum rises, the color of the rubbed area will become light brown, then medium brown, and then dark brown. When it's DARK BROWN, get ready! Drop the pine stick, lower your goggles, and grab the filler rod because the aluminum is about ready to start melting.
2. Mark part of the weld area with blue carpenter's

chalk. When the blue color changes to white it's your cue to be ready—the aluminum is almost hot enough to weld.

3. As the metal is heated, rub or scratch the filler rod against the surface of the weld area. Just before the aluminum becomes molten it gets soft and "mushy." With a little practice you can "feel" this condition with the rod.

WELD JOINTS IN ALUMINUM SHEET

Joints for welds in wrought sheet aluminum are prepared in much the same manner as those for welds in sheet steel. Heavier sections must be beveled and notched.

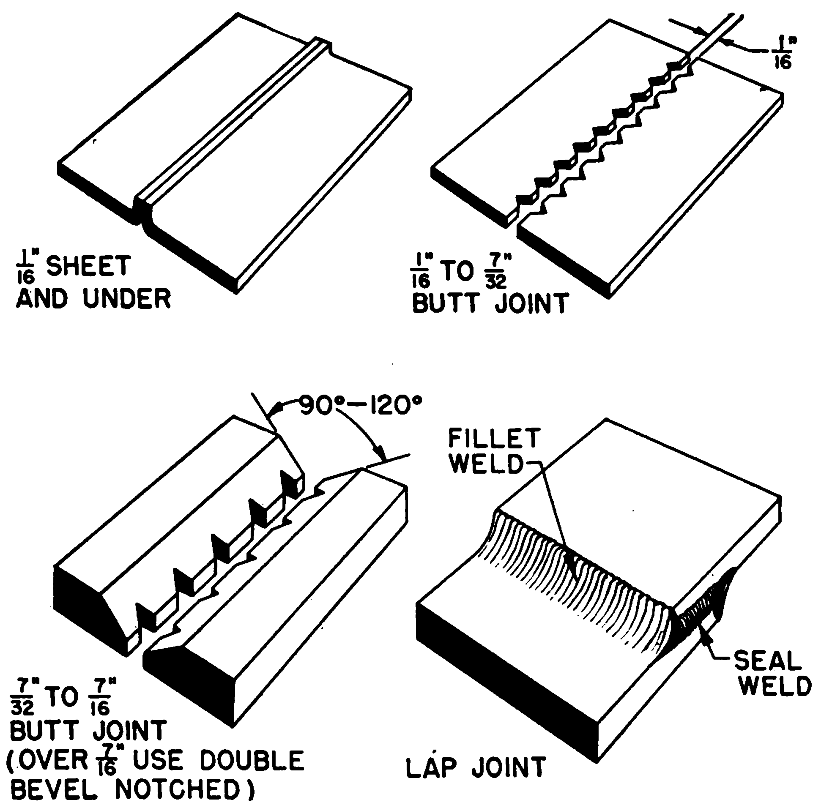

Figure 98.—Weld joints for aluminum.

Sheet stock is easier to weld if it is "backed up" with a strip, bar, or sheet of copper. The backing keeps the molten aluminum from dropping out of the weld area. The backing metal should fit snugly under the joint. You can clamp it in place.

Before you start a weld on aluminum check these points—

Is the joint properly shaped and spaced?
Is the joint clean?
Have you selected the right filler rod?
Have you applied the right flux?

NOW TRY ONE

Get everything ready for a thin-sheet butt weld like the one shown at the upper left in figure 98. Adjust the flame so that it is SOFT and NEUTRAL. Start playing the flame over the weld area.

Hold the torch at a considerable slant at first, so that the flame won't blow holes through the metal. An angle of 45 degrees is about right. The heavier the metal, the more nearly perpendicular you can hold the torch.

Heat both edges of the joint UNIFORMLY so that the heat will be well spread around in the weld area. Don't hold the torch too long in one spot. If you do, there is danger that the whole area around the weld will crumble and fall away.

When the metal begins to melt, quickly insert the end of the preheated filler rod into the molten pool in such a way that it can be melted UNDER THE SURFACE of the pool. Do NOT stir the puddle or push the rod through it. Be careful that the filler metal enters the weld ONLY where the base metal has been brought to a molten condition. You won't get good fusion if you allow molten filler metal to flow ahead OVER the unmelted edges of the joint.

Remember that there is no radical color change before the aluminum melts. The metal may be solid one instant and then, without any easily apparent change in appearance, melt and sag. Here is where your ability to judge and estimate the temperature of the metal pays dividends. And it's also why it is a good idea to use a backing strip, particularly under thin metal.

In *A* of figure 99, the aluminum is being heated. In *B* the base metal is starting to melt. In *C* the filler rod is dipped into the molten puddle and allowed to melt with it. In *D* the filler rod is being lifted while the torch flame is moved forward to continue the melting. In *E* the rod dipping process is being repeated. *F* shows the continuous dipping motion of the filler rod as you progress rapidly along the joint.

FASTER PLEASE

WORK RAPIDLY. Otherwise you can hardly help holding the flame in contact with molten metal at some point or other. If you hesitate too long, don't be surprised to see that you've burned holes right through the metal. A strong, well-fused joint in aluminum sheet will show a bead on BOTH surfaces of the joint.

Another difficulty in welding aluminum is that it becomes solid very quickly after the flame is moved away. You can't make it flow as you can molten steel. With practice, however, you'll be able to get good fusion and

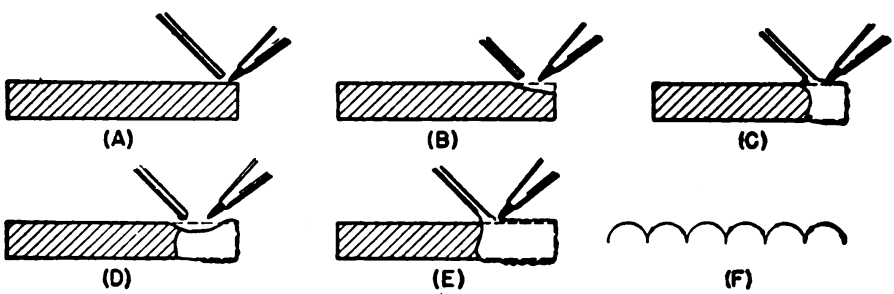

Figure 99.—Handling the filler rod.

to build up a smooth ripple weld of the right height. When you really get the knack of welding aluminum you may find that you can weld it easier, and much faster, than you can weld steel.

After you finish welding a joint, wash off ALL the flux that may be left sticking to the metal. Otherwise, the elements of the flux will attack and corrode the base metal if moisture is present. To remove the flux just scrub the joint in hot water. If the joint is located in a place hard to reach, dunk it in a cold bath of 10 percent sulphuric acid and 90 percent water.

TEST YOURSELF

After you get the "feel" of aluminum welding, test yourself on the welds shown in figure 100. The fillet weld is a tough one because the two pieces vary in thickness. The upright piece should be at least 4 inches long (4 Minimum).

WELDING ALUMINUM CASTINGS

Castings are welded in much the same way as wrought

aluminum sheets so far as cleaning, fluxing, and flame adjustment are concerned. The filler rod for castings is usually 43S (5% silicon).

The welding of some castings is complicated by intricate designs. But the main problem is always one of HEAT CONTROL. All castings should be preheated to 700 to 800°F. Small jobs are easily heated with the welding torch, but large castings require the use of some type of furnace.

You can make a temporary furnace by building up fire brick around the casting and covering the top with sheet asbestos. An oil-burning torch may be used to provide

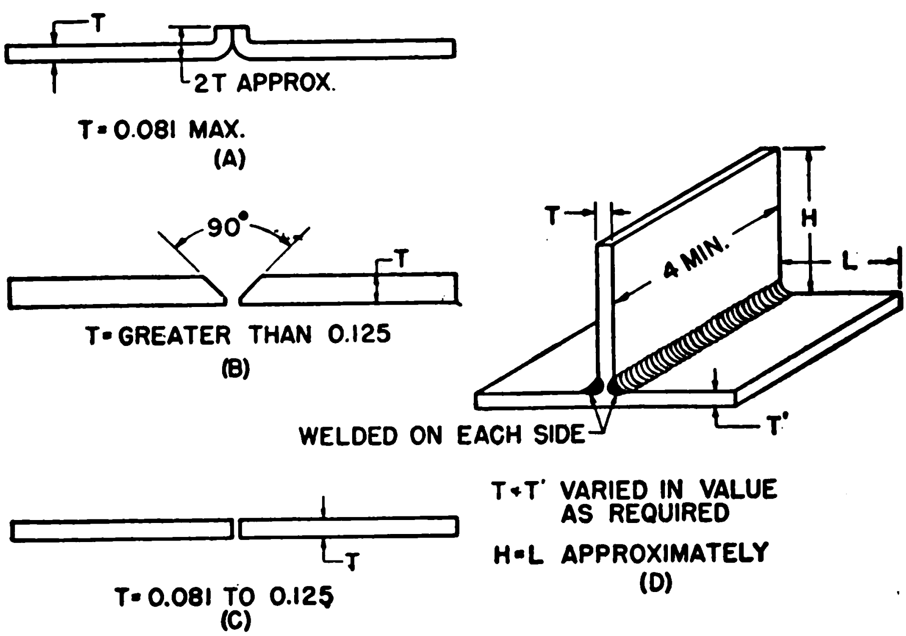

Figure 100.—Test yourself on these welds.

the heat. Uniform heating and cooling help to prevent the formation of internal residual strains in the metal.

If you think there is any danger of a joint falling through, back it up with shaped strips of copper. Clamp these strips securely under the weld area.

Check the temperature of a casting during the preheating period by the usual methods. Experienced welders sometimes check the temperature by tapping the metal LIGHTLY with a hammer. A cold casting gives off a loud, metallic sound when struck. As the metal gets hotter and hotter, the sound gets duller and duller. But only an experienced welder should use this method. It

takes a highly trained ear to tell when the casting is just about ready for welding. And if the aluminum is tapped too hard just before it reaches the melting point, it may break. NEVER GET ROUGH WITH ALUMINUM WHILE IT IS HOT. At a temperature of 500°F. aluminum is only one-half as strong as it is at room temperature. As the temperature goes up, the aluminum gets weaker and weaker. This characteristic is referred to, commonly, as HOT-SHORTNESS.

When you weld a HEAT-TREATED CASTING you destroy the effects of the heat treatment. If the casting is to have its original strength it will have to be heat treated again after it is welded. Chapter 14 tells you how to do this.

CHAPTER 8

ARC-WELDING STEEL

HEAVYWEIGHT CHAMPION

When 40-pound plate and heavy steel castings are to be welded, the ARC WELDER is the machine you'll use. Heavy jobs CAN be gas-welded but it takes more time and is a tedious job. Also, when gas is used the job requires extensive preheating and postheating or heat treatment. So, generally speaking, you'll use the torch on sheet metals (1/8 inch and under) and the arc for the big jobs.

The average Metalsmith aboard ship doesn't do much arc welding—only occasional jobs. Often the metalsmith shop won't even have its own welding machine, and will have to borrow the shipfitter's outfit.

Most of the arc welding you'll do will be on steel pipe joints, pipe hangers, cable clips, and broken machinery parts. In an emergency you may help the shipfitters weld plate, stanchions, or frames.

ARC WELDING EQUIPMENT

For arc welding, the ship's regular direct current must be changed by an ARC WELDING MACHINE to a current that has LOW VOLTAGE (17 to 30) and HIGH AMPERAGE (usually

30 to 300). The arc welding machine does this by means of a d–c motor which drives a special d–c generator.

Some ships are equipped with alternating current welding machines having box type transformers. To avoid long leads, these machines are located in strategic spots throughout the ship. Alternating current welding requires special electrodes but you have no polarity to worry about. Otherwise the procedures and techniques are about the same as for d–c welding.

The CONTROLS of the welding machine must be set to provide the correct current for the electrode used and for the position in which the weld is made. No specific directions are given here for setting controls because they vary on the different types and sizes of machines made by different manufacturers. Get an experienced arc welder to "break you in" on the machine you'll use. As you gain experience, you will learn to make the control adjustments necessary for producing a perfect weld.

For welding in the FLAT POSITION ONLY, the following table will serve as a general guide for any d–c arc welder, so far as amperage and voltage are concerned.

DIAMETER OF ELECTRODE	WELDING CURRENT AMPERE RANGE	ARC VOLTAGE RANGE
1/16"	30–60	19–23
3/32"	50–100	20–22
1/8"	80–135	23–27
5/32"	110–180	24–29
3/16"	150–220	26–30

> NOTE: Aboard ship, adjustments of current value must be made frequently. This is due to the fact that the source of the current is also the source of current for many other machines and mechanisms. If you have trouble making a good weld, it may be due to current fluctuations.

Most of your arc welding will be on steel. For filler metal, use heavy-coated welding rods which are called ELECTRODES. As an electrode melts, the coating on the rod forms a shield for the arc area, thus aiding in maintaining a uniform temperature. It also forms a heavy coating of slag over the weld metal.

A clamp-type ELECTRODE HOLDER is connected to an insulated LEAD or cable, which is in turn connected to the

welding machine. Another cable, known as the GROUND, connects the welding machine to the base metal. The ARC, formed between the end of the electrode and the base metal, completes the electric circuit. The energy of the electric current is dissipated at the arc and provides the welding heat.

Other equipment includes the FACE MASK, HEAVY GLOVES, and LEATHER CLOTHING, to protect your body from the infra-red and ultra-violet rays of the arc, and from flying metal, slag, and sparks. CHIPPING HAMMERS, COLD CHISELS and WIRE BRUSHES are used to remove the slag after welding.

MORE ABOUT THE ARC

The ARC is the distance between the end of the electrode and the base metal across which the current jumps. If the electrode end contacts the weld metal you get a dead short. If the end of the electrode is too far away from the base metal, the circuit is broken and you "lose

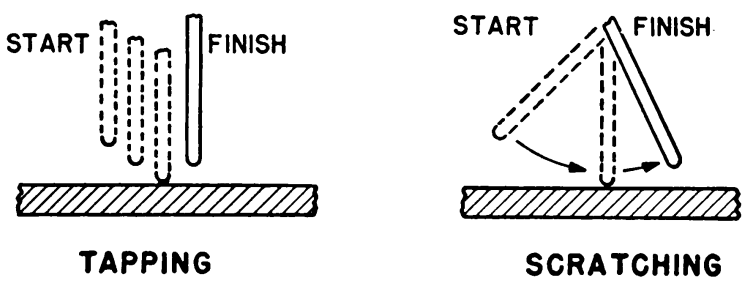

Figure 101.—Striking the arc.

the arc." But, when you keep the end of the electrode spaced the correct distance from the base metal, you get a continuous spark—the WELDING ARC.

The correct arc space, or gap, is about equal to the diameter of the welding electrode rod.

The skills involved in arc welding are centered around the control of the arc. Your first job will be to learn how to START THE ARC. This is done by touching the electrode to the base metal MOMENTARILY. As soon as contact is made the electrode is quickly withdrawn to form the arc and the weld is begun. Two methods of arc starting are shown in figure 101. Practice both of these methods so you'll be able to "strike an arc" when you're welding in ANY position.

If you're a beginner, you'll probably be a little nervous and "stick" the electrode to the base metal on your first attempt. When that happens, just give the electrode a quick twist to free it. If that method fails, unclamp the holder from the electrode, secure the holder, and chip the electrode free with a cold chisel.

D–C POLARITY

There are only two ways you can hook up the d–c arc welder—with STRAIGHT POLARITY and with REVERSE POLARITY. Ordinarily you'll use straight polarity but your

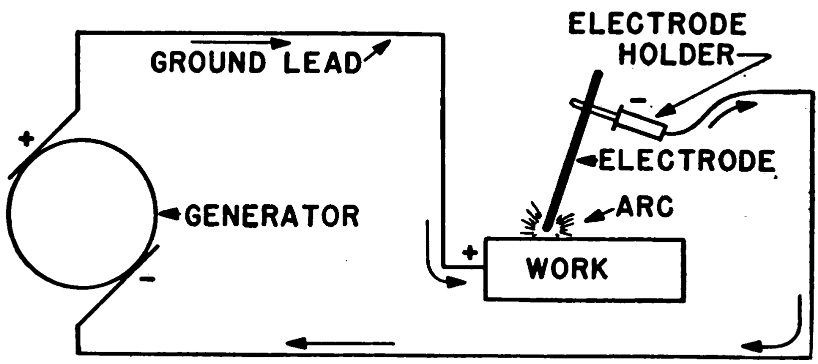

Figure 102.—Straight polarity.

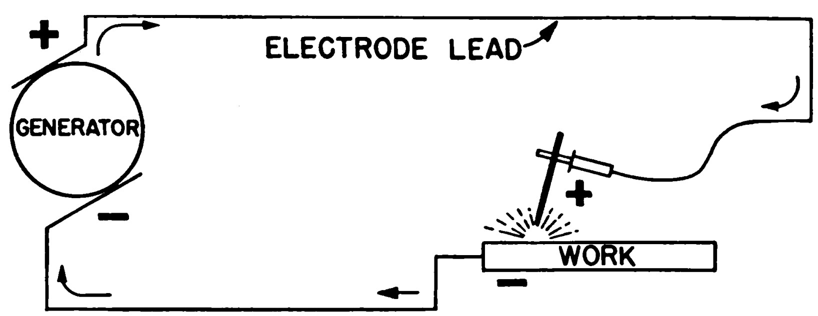

Figure 103.—Reverse polarity.

best bet is to follow the recommendations of the manufacturer of the machine and the manufacturer of the electrode used.

Straight polarity is obtained by connecting the electrode holder to the NEGATIVE cable of the machine, and the positive cable to the base metal. For reverse polarity, the POSITIVE cable is connected to the electrode holder and the negative cable to the base metal. Figure 102 and 103 show how.

If you use an uncoated or light-coated NEGATIVE electrode, the majority of the welding heat is concentrated

in the base metal. When you use heavy-coated electrodes always follow the manufacturer's instructions, because the thickness and composition of the coating greatly influences the distribution of heat.

GENERAL ARC WELDING TECHNIQUES

If you're a good gas welder, you'll find that it is not difficult to learn arc welding. The rules for penetration,

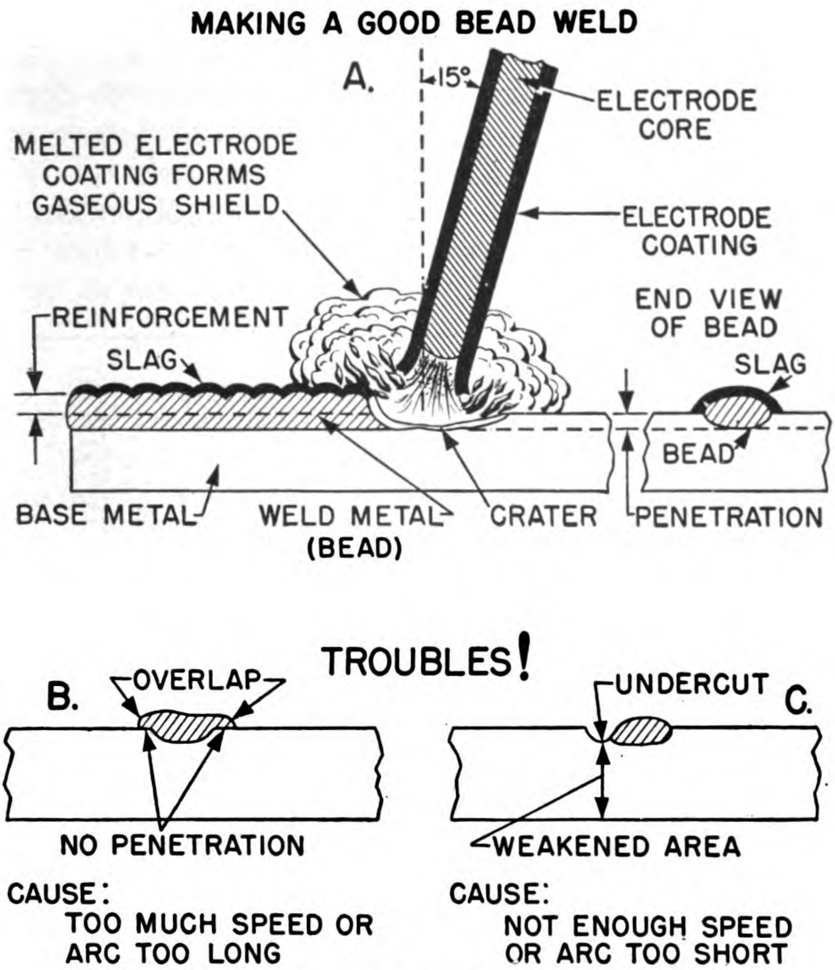

Figure 104.—Arc control.

fusion, reinforcement, and strength apply to both kinds of welding. The new techniques you must learn are mostly concerned with arc control.

Always advance the arc at a UNIFORM rate of speed to prevent UNDERCUTTING and OVERLAPPING. Figure 104*A* shows a good weld. *B* and *C* of the same figure show what happens when you go too fast or too slow.

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If the arc has a tendency to "blow" you can correct the trouble by shifting the ground cable clamp to another location. Continued blowing will cause uneven burning of the electrode and gouging of the weld metal.

If at all possible, arrange your work so that you can do the welding in the FLAT POSITION—it's easier and much faster.

When it is necessary to change electrodes before a weld is completed, withdraw the old electrode SLOWLY upward from the weld until the arc is broken. Otherwise you'll have a gouged out place known as a CRATER. Incidentally, the depth of the crater indicates the depth of penetration. Slag must always be removed before an incompleted weld is "picked up" and continued.

If several beads must be run on one job, allow each bead to cool before you start another.

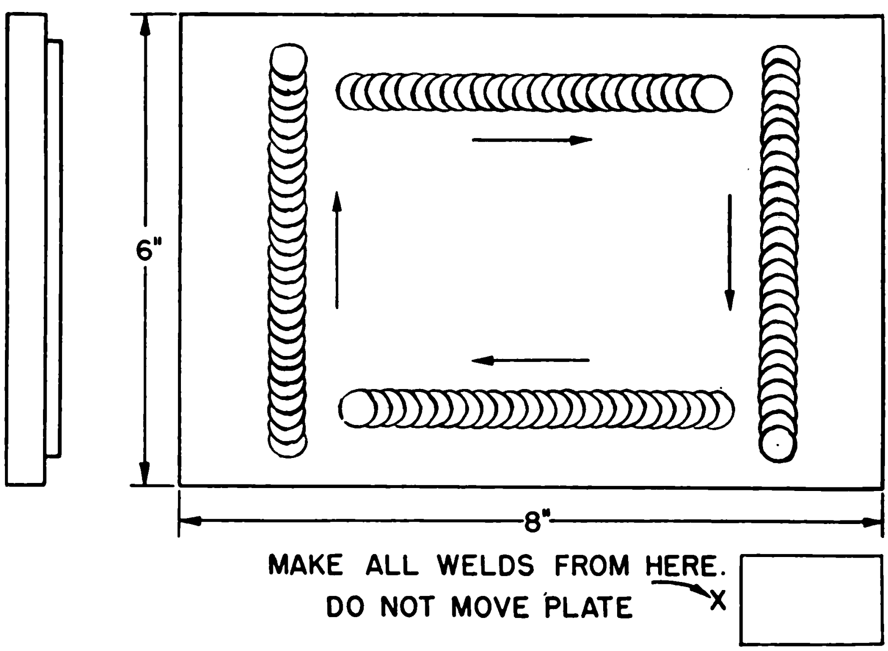


Figure 105.—Practice job 1.

Slag can be removed by scraping along the toes of the weld with a cold chisel. Complete the cleaning with a wire brush. On big jobs it's OK to use an air hammer and chisel.

Generally speaking, joints for arc welds are prepared and tacked about the same as for backhand gas welding. Edges for butt joints are usually beveled to an included

angle of 60° (30° on each edge). A bevel of 45° is used on tee joints.

Edges may be beveled on a grinder or with a gas cutting torch. They should be finished smoothly with all slag and scale removed from the joint.

INFORMATION PLEASE

Get all the help, advice, and suggestions you can from experienced welders. Study all the available books on welding and try to have at least one good book that you can use as a reference.

Check up and find out if the manufacturer of the welding machine you use puts out any instruction books and guides. Several manufacturers publish excellent welding books which they sell at cost—usually $1.00 or $1.50. These books are worth far more than their cost. It will pay you to get one for your own use if none is provided.

ARC WELDING PRACTICE

After you have learned to strike the arc and keep it going, the next step is to practice running some beads on a piece of ¼ inch plate in the flat position. Use scrap stock for practice work when it's available. Surveyed machine parts and castings provide excellent practice material.

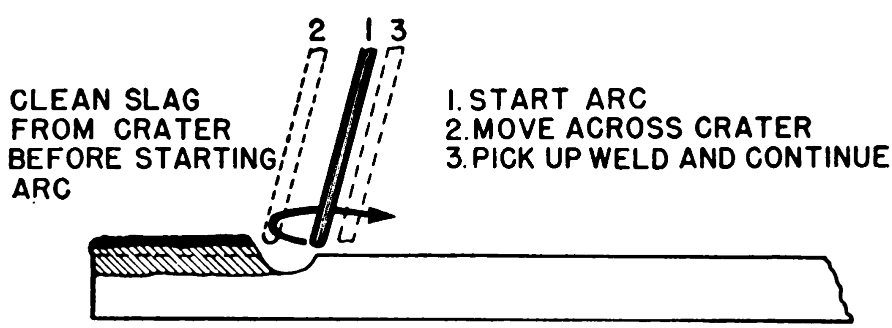


Figure 106.—"Picking up" the weld.

For your first practice job, run the beads shown in figure 105. First of all, set your machine controls to obtain the desired heat. Then, after you start your arc, hold the electrode as shown in figure 104*A* and run the bead. When you finish the job, chip off some of the top of the weld metal to observe the degree of fusion and depth of penetration.

If you break the arc—and you will at first—you'll have to clean the slag from the last part of the weld before you strike the arc again. Then start the arc and pick up the weld as shown in figure 106.

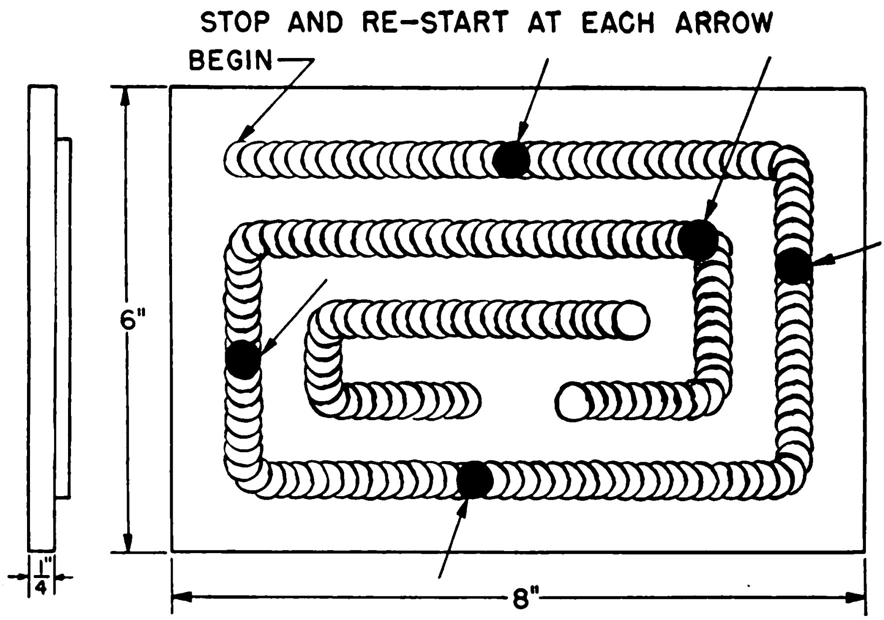


Figure 107.—Practice job 2.

Job 2 is similar to job 1 except that the arc is intentionally broken at the points indicated by the arrows (figure 107). This job is designed to test your ability to pick up and continue a weld.

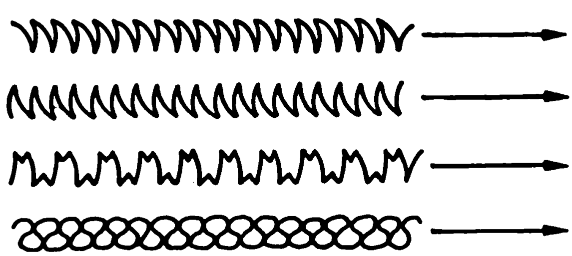


Figure 108.—Weaves for wide welds.

ELECTRODE WEAVING

For some jobs it is desirable to make the weld face wider than is possible with the "straight line" beading technique. To get a wide weld, move the electrode from side to side approximately 4 diameters of the electrode rod. This sidewise motion is called WEAVING, just as it is

in gas welding. Some typical weaves are shown in figure 108.

The weave pattern must be uniform if the weld is to be good. If the weave is not uniform, there is danger of poor fusion at the toes (edges) of the weld and of getting trapped slag in the center.

BUTT WELDS

Now you are ready to join two pieces of metal. Weld the job shown in figure 109. Use small tack welds.

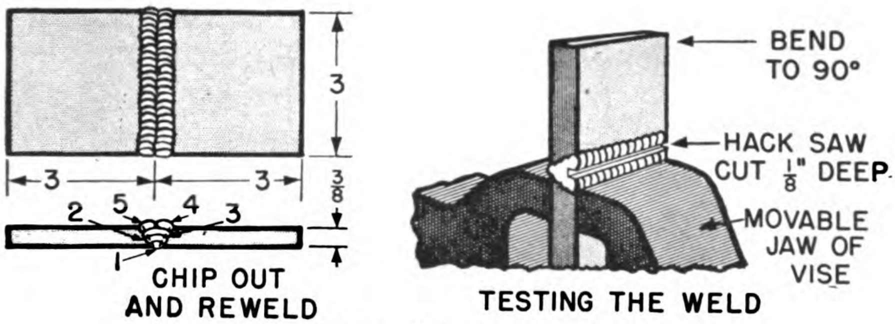


Figure 109.—Job 3 (V-butt weld).

In this weld you must get COMPLETE FUSION at the ROOT of the joint on the FIRST pass. Notice that the weld is made in layers. The surface of each layer must be cleared of slag before the next layer is welded. After three layers (1, 2, and 3) are deposited, turn the plate over and chip out the root of the weld to sound metal. Next deposit a

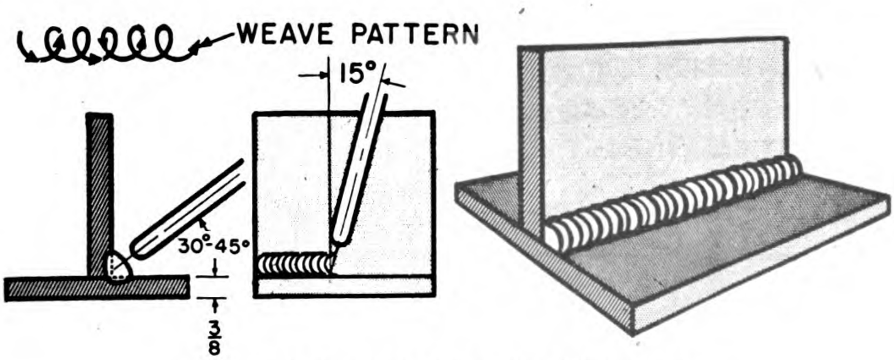


Figure 110.—Job 4 (bead-welded fillet).

single layer in that groove. Then weld the two top layers. Test this weld by the method shown at the right in figure 109. Check for slag inclusions, porosity (undesirable large pores), and lack of fusion. Practice this weld until

you are able to make a sound, well-fused joint—one that doesn't crack when it's tested.

FILLET WELDS

For your first fillet weld, use a straight beading technique to make the tee weld shown in figure 110. Tack weld—then start the electrode as shown. Take special care to prevent undercutting, overlapping, and poor fusion. Test this piece by flattening the standing piece against the base piece.

The next practice job is to make the weld shown in figure 111. The fillet should be $^3/_8$ inch on each leg of the weld. Practice making several weave patterns on this job.

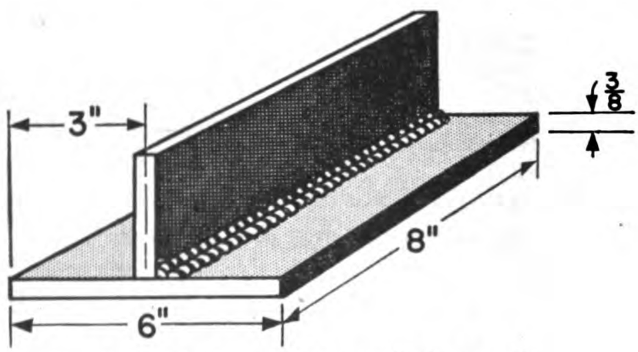


Figure 111.—Job 5 (3/8" fillet weld).

The terms used to describe the SHAPE and SIZE of a fillet weld are shown in figure 112.

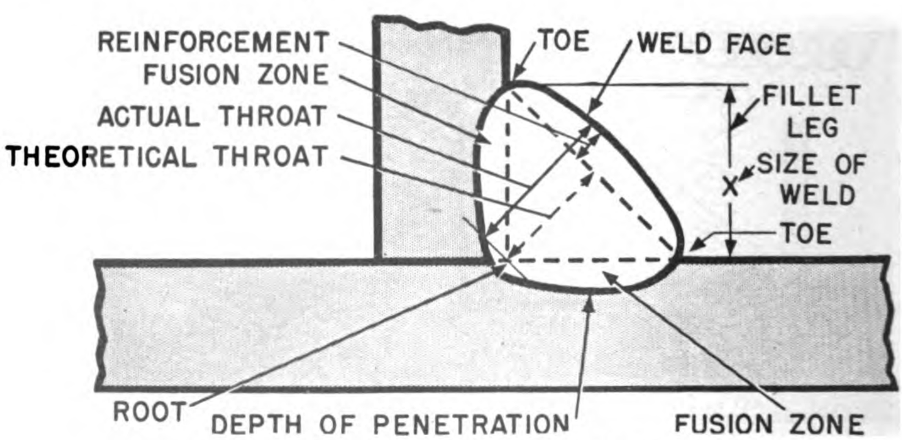


Figure 112.—The fillet weld terminology.

Fillets on lap welds are made in much the same manner as those for tee joints.

WELDS ON VERTICAL SURFACES

To run a HORIZONTAL BEAD on a VERTICAL SURFACE, hold the electrode as shown in figure 113. Use a shorter arc and a lower current (about 150 amps) than for a similar flat position weld.

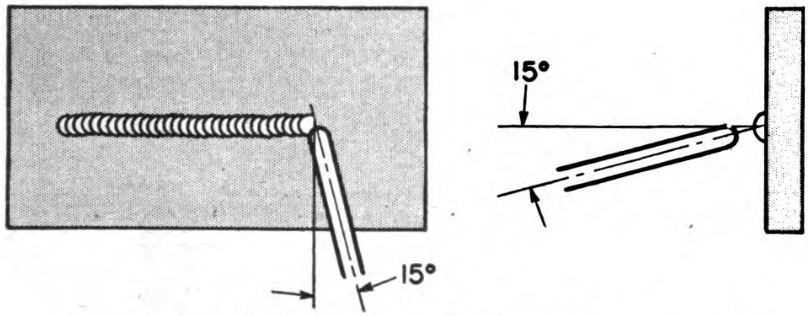


Figure 113.—Job 6 (Horizontal bead on vertical surface).

When you're making a VERTICAL BEAD on a VERTICAL SURFACE, weld "uphill." Set the current at 125 amperes. Hold the electrode so that it is about perpendicular to the plate. Try running a vertical bead on a vertical surface for your 7th practice job.

After you're pretty good at running plain beads on a vertical surface, try the vertical butt weld, job 8, figure 114. Two systems or techniques are shown. A simple triangular weave is used at *A*. The technique shown at *B* is faster because a higher current can be used. In this method, the electrode is whipped up the root of the groove

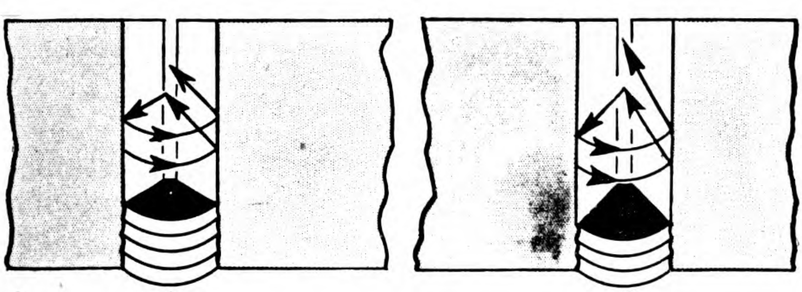


Figure 114.—Job 8 (Vertical butt welds).

from ¾ to 1 inch, with an increase in arc length at the end of the sweep. The whipping action gives the molten metal a chance to chill and prevents the weld metal from running.

Test this weld for fusion and soundness. Don't be surprised if the first one is not so good. Vertical surface welds are much more difficult than flat position welds. Continue practicing until you get a good vertical butt weld.

HORIZONTAL BUTT WELDS on vertical surfaces are welded as shown in figure 115. A small bead is run in the root of the groove. This is cleaned and the main weld made as shown. The root weld is then chipped out to sound metal and rewelded from the other surface.

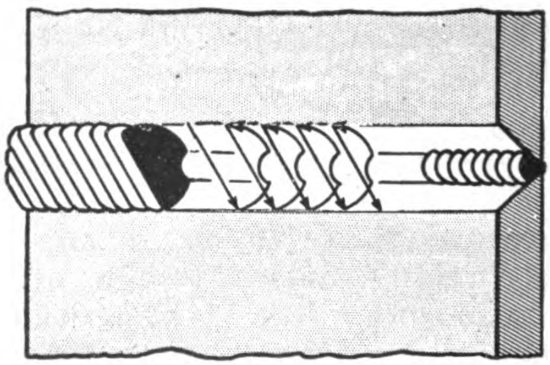


Figure 115.—Job 9 (Horizontal butt weld).

OVERHEAD WELDS

Your first step in handling overhead welds is to learn to deposit an overhead bead. Hold the electrode in the position shown in figure 116. Deposit short strings of

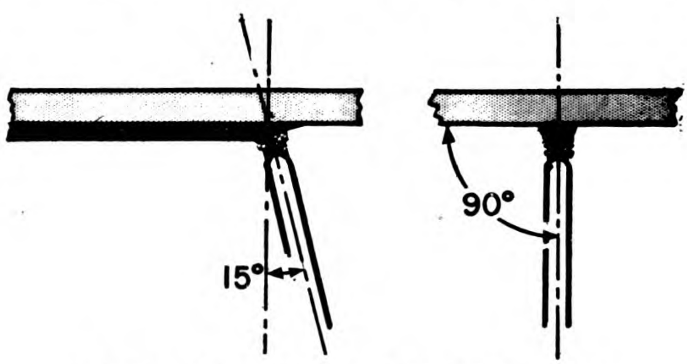


Figure 116.—Job 10 (Overhead practice).

beads to develop your ability to strike an arc IN ANY POSITION. Then make some wider deposits by using the crescent shaped weaving motion.

Overhead butt welds are difficult to make because there is a tendency for the arc to melt through the thin edges at

the root of the weld. If the weld metal appears to be getting too hot, whip the electrode along the joint ahead of the weld. Keep the arc short but be ready to lengthen it if the arc starts to burn through the root of the weld. Now practice the weld shown in figure 117. Use ⅛ inch rod and 120 amperes of current.

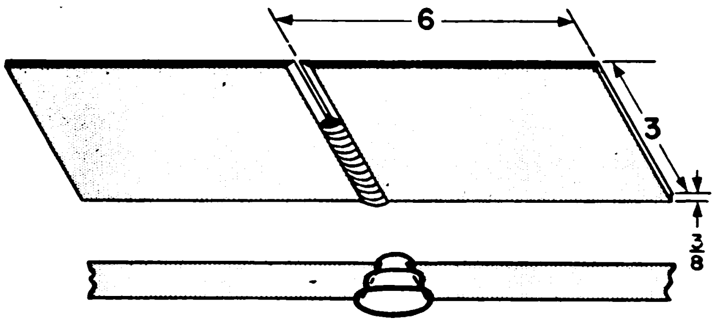


Figure 117.—Job 11 (Overhead butt weld).

The practice jobs shown in figure 118 are welds used on overhead lap and T- joints. These welds are easier to make than overhead butt welds because there is less danger of burning through the metal.

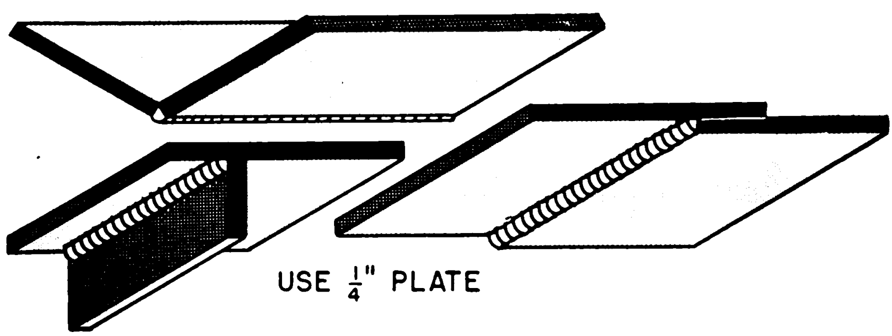


Figure 118.—Jobs 12, 13, and 14 (overhead).

SAFETY RULES FOR ARC WELDING

FIRE PROTECTION—

POST FIRE WATCHES for any welding job done away from the shop.

DON'T WELD in the vicinity of INFLAMMABLE vapors, gases, liquids, or other material which may be ignited by the arc or spatters of hot metal.

Never weld on bulkheads or decks without finding out whether it is SAFE on the opposite side.

Do not weld on sealed containers or on ANY containers which have held ANY INFLAMMABLE MATERIAL.

PROVIDE plenty of VENTILATION if you are welding gal-

vanized metal or are working in an enclosed, or partially enclosed space. Avoid welding where dust has accumulated or where the air is full of dust.

Keep the shop or welding area CLEAN and the bench and deck CLEAR of scrap metal, electrode stubs, tools and materials. Pay particular attention to where you discard hot electrode stubs—fires have been started by them.

CHECK WELDING LEADS (cables) frequently. Repair or replace damaged equipment. If a cable gets hot enough so that you can feel the heat you may be sure either that the cable is overloaded or that the cable wires have begun to separate in the hot locality.

Always secure the ELECTRODE HOLDER on an electrically INSULATED SUPPORT. Careless handling of this holder may strike an arc and start a fire.

EYE PROTECTION—

ALWAYS WEAR YOUR HELMET while welding or when assisting a welder. It protects your eyes from glare and your whole face from the harmful effects of spattering metal, ultra-violet rays, and infra-red rays. The helmet window should be of safety glass. This safety glass should be covered with a clear glass to protect it from molten spatter.

Wear clear glass safety goggles when you're grinding bevels or removing slag.

Warn inexperienced personnel not to look at the arc. If you use a helper, provide him with a helmet.

CLOTHING—

WEAR LEATHER GLOVES AND SLEEVES OR JACKETS. Aprons of leather help to prevent body burns. Woolen clothing is safer than cotton. NO ITEM OF CLOTHING OR EQUIPMENT SHOULD BE ALLOWED TO BECOME OILY.

HEALTH HAZARDS AND VENTILATION—

PROVIDE PLENTY OF VENTILATION when you are welding on material that has been coated with lead, zinc, or paint.

CARE OF EQUIPMENT—

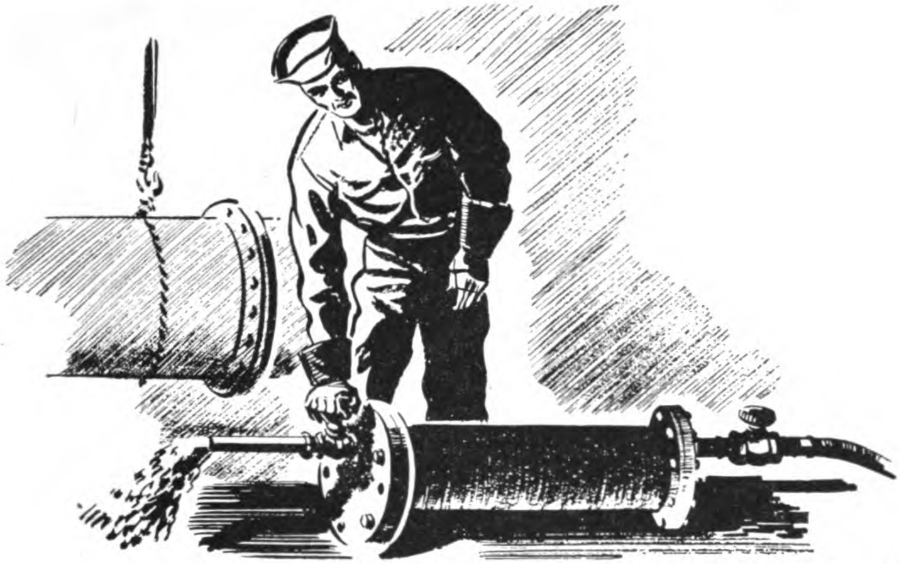
AVOID STORING the arc welding machine in DUSTY or DAMP PLACES. Dust and water must be kept out of the bearings and windings.

AVOID OPERATING a machine continuously under OVERLOAD.

Do NOT make adjustments to controls during welding.

DON'T ATTEMPT REPAIRS to the welding machine. Electrician's mates will make the necessary repairs.

ALWAYS BE CAREFUL
AND
KNOW
THE LOCATION OF
FIRE EXTINGUISHERS
AND
FIRE PLUGS



CHAPTER 9

COPPERSMITHING

YOUR WORK WITH COPPER

As a Metalsmith you must know how to shape, fit, solder, and braze copper pipes, tubes, ducts, tanks, and floats. Most of your work will be repair work—replacing or overhauling a damaged or worn-out part. Usually you'll be able to use the old piece or part as a pattern when you lay out the new piece.

Copper is used extensively in ship construction because it is CORROSION RESISTANT, EASILY SHAPED, and EASILY BRAZED. Ordinary copper tubing and pipe is used for many of the piping systems—lubricating oil, gasoline, hydraulic, refrigeration, air, steam exhaust, steam for heating, and gas ejection for guns. Tin-coated copper tubes are used for brine lines, flushing systems, evaporator systems, and fire mains. Copper is NOT used in high-temperature systems. It is seldom used in high-pressure systems although air lines are sometimes made of heavy, thick-walled copper pipe.

Although copper is easy to shape and bend, it will split and crack when it begins to WORK-HARDEN. The term work-harden refers to the hardening of the metal as it is being pounded or bent into shape. Copper becomes so

hard it gets brittle—so brittle it cracks and splits. The only way this can be prevented is by ANNEALING. (Annealing, a softening heat-treatment, is discussed in Chapter 13.) Sometimes copper will need to be annealed from 12 to 15 times as it is being worked.

Joints in copper pipes and tubes are threaded, held with flare fittings, flanged, soldered, brass-brazed, or silver-brazed. The last method—silver-brazing—is used extensively for repair work. You read about it in Chapter 6.

SPECIAL SHAPING TOOLS

Ordinary tools such as ball peen, cross-peen, and sledge hammers, rawhide and wood mallets, cold chisels, snips, stakes, and files are used for working copper. Sheets may

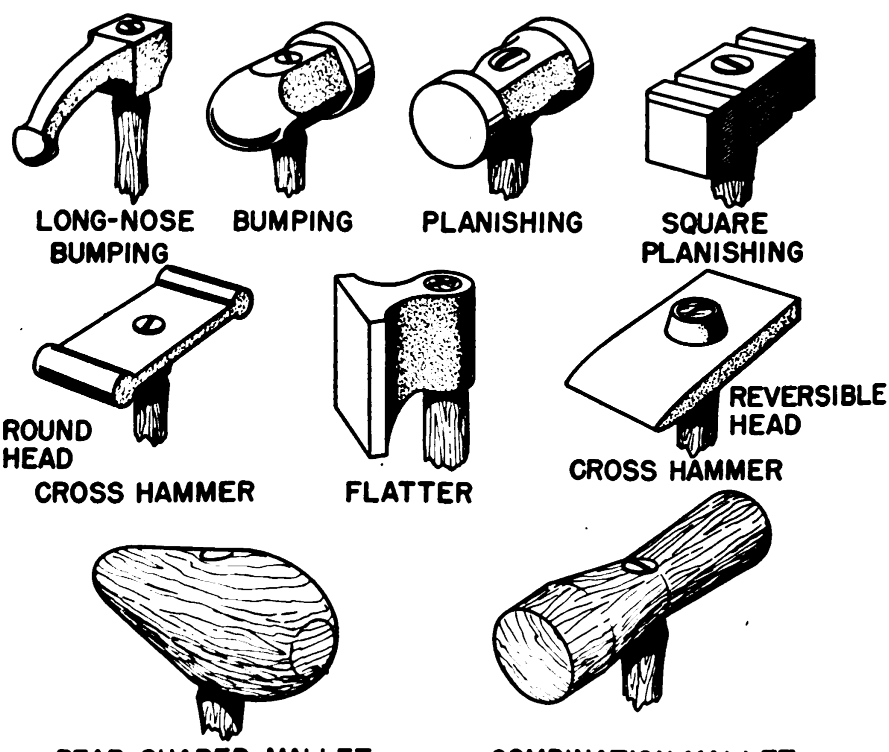


Figure 119.—Special pounding tools.

be formed with bar-folders, brakes, slip-rolls, and rotary machines. In addition a number of special tools are used. See figure 119.

BUMPING HAMMERS are used to shape and flare copper sheets, pipes, and tubes. The long-nosed bumping hammer is designed for use on the inside of cylinders and in other hard-to-reach places.

PLANISHING HAMMERS are used to smooth and harden copper. Planishing is done with a series of light, uniform hammer blows. The copper is "backed up" with a stake, head, or hand dolly. Flat pieces are held on the anvil.

FLATTERS or "spankers" are used when working copper over a mandrel or stake. Flatters are of several shapes

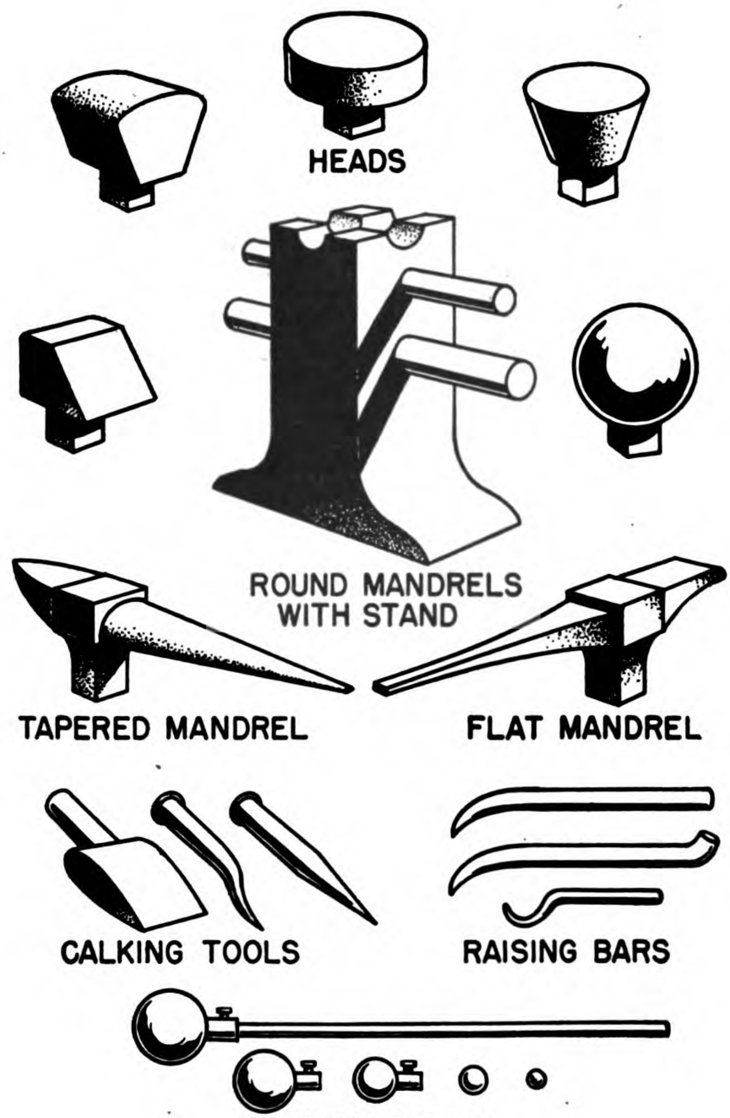


Figure 120.—Shaping and forming equipment.

and sizes. Some are designed so that they may be struck with a hammer.

CROSS HAMMERS are used to form edges and shoulders and for smoothing bumps and wrinkles.

PEAR-SHAPED MALLETS, made of wood, are used much the same as bumping hammers.

The tools shown in figure 119 are used to pound metal into shape over the MANDRELS and special HEADS shown in figure 120. BUMPING BALLS are used to shape pipes from the inside. You'll use RAISING BARS when you form openings for cup and branch joints.

USE OF ACIDS

Acids are used primarily for cleaning metals—not only copper but other metals as well. Acids dissolve and remove the OXIDES. Acids should be handled or used ONLY in glass or lead containers. Wear goggles and rubber gloves when you handle acids or work near them. And your clothes will last longer if you wear a rubber or asbestos apron.

If acid does splash in your eyes, or on your body, WASH THOROUGHLY AT ONCE with clear cold water. If it's bad, head for sick bay immediately after you wash the acid off with the water.

NEVER POUR WATER INTO ACID—the mixture will boil violently and may explode. Always pour the acid into the water.

After you have cleaned the metal with acid, wash it clean with cold water. Then dry it with a torch flame or with steam.

SULFURIC ACID may be used to clean copper, brass, and bronze. This acid is usually diluted by pouring one part of acid INTO ten parts of water. Small metal parts may be heated to the same temperature and SWABBED with the acid solution.

MURIATIC (commercial hydrochloric) ACID may be used for cleaning almost any kind of metal. Don't heat the metal for cleaning with muriatic acid as heat weakens the acid.

NITRIC ACID is seldom used—it's too strong. Nitric acid eats the metal away rapidly, especially when it's mixed with muriatic acid.

Copper piping is cleaned by dipping it into a sulfuric acid solution. After washing, the acid is neutralized by dipping the pipe in a solution of one pound of soda ash in seven gallons of water. Soak the copper piping for 20

minutes—then wash again. Steam to remove any remaining foreign particles and to dry the pipe.

PIPE FLANGES

Several types of flanges are used for joining sections of copper and copper-alloy pipe. Flanged pipes allow whole sections of pipe to be removed quickly for cleaning, replacement, or repair. Matching flanges are secured to the ends to be joined, a gasket is installed, and the flanges drawn together and held with bolts. The size of a flange is given as its INSIDE DIAMETER in inches.

Flanges are usually secured to pipe or tubing sections by spelter-brazing or silver-brazing. Because spelter-brazing requires considerable space and equipment, it is

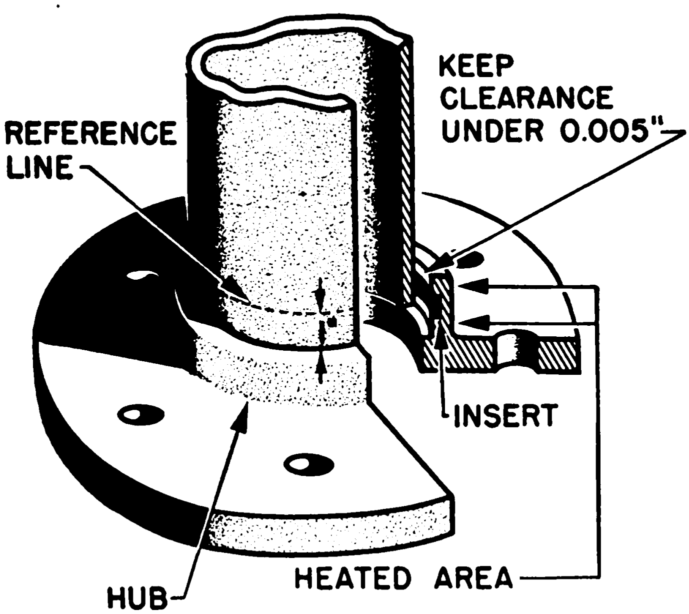


Figure 121.—Silver-brazed flange.

being replaced by silver-brazing for shipboard use. (Remember that silver-brazing is sometimes called silver-soldering.) Heat for silver-brazing is provided by torches burning oxygen-acetylene or oxygen-hydrogen.

When a flange is brazed on, the pipe should be in a vertical position. However, it is possible to get good results with silver solder in almost any position. That's why silver-brazing is used extensively in modern fighting ships.

SILVER-BRAZED FLANGES should fit snugly around the pipe, with only a few thousandths of an inch clearance, as

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indicated in figure 121. These flanges are cast of "Composition M," a copper alloy containing 1.5 percent zinc, 5.5 percent tin, 1 percent nickel, 1 percent lead, and the remainder copper. Notice in figure 121 that these flanges have high collars. Notice also the INSERT in the flange. This insert of silver solder is placed in the circular groove of the flange by the manufacturer. When the collar of the flange is fluxed and heated, the silver insert melts and flows through the joint. Plenty of flux and uniform heat insures a good joint.

Silver-brazed joints are NOT recommended for operating temperatures exceeding 450°F.

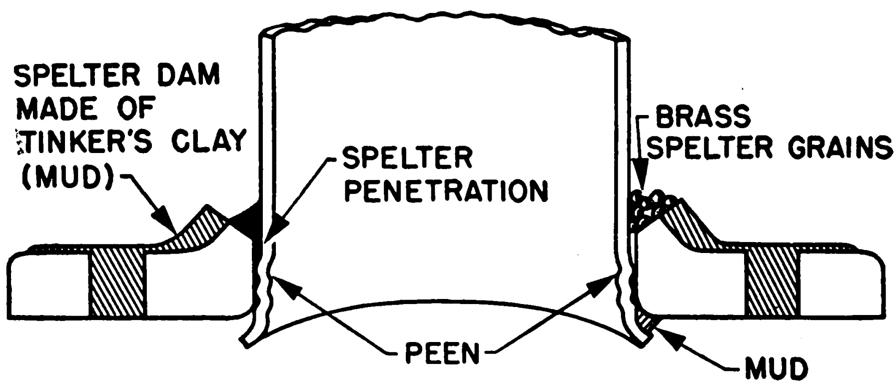


Figure 122.—Spelter-brazed flange.

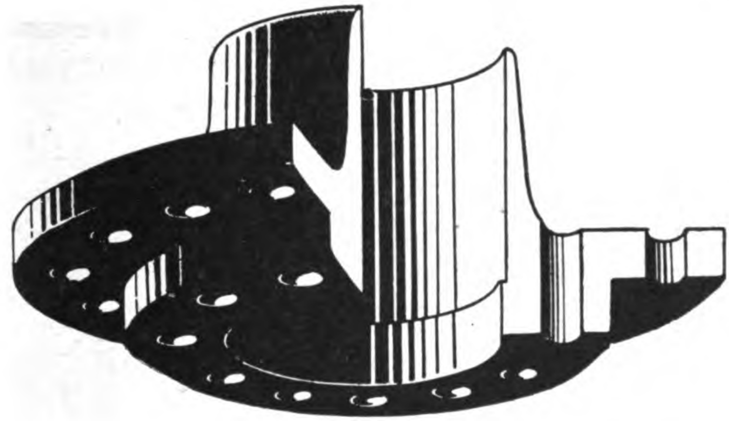
SPELTER-BRAZED or BRASS-BRAZED FLANGES have short, beveled collars. These flanges are cast of "Composition F," which is 85 percent copper and 15 percent zinc. Figure 122 shows this type of flange, along with a typical spelter-brazing set-up. For spelter-brazing, the pipe is fitted into the flange, peened near the face and mudded up as shown. After the brazing is completed, the end of the pipe is cleaned and then peened smoothly against the flange face.

IT'S OK TO REPAIR A SPELTER-BRAZED JOB BY SILVER-BRAZING.

BULKHEAD FLANGES for copper piping may be of either "M" or "F" metal depending on whether they are to be spelter-brazed or silver-brazed. A silver-brazed bulkhead flange is shown in figure 123.

The bulkhead flange has two circles of holes—the outside set for bolting to the bulkhead, and the inside set for bolting to a regular flange. Special insulating gaskets are used for steam lines.

VAN STONE flanges (figure 124) are not brazed but are held only by clamping pressure (bolts). The end of the pipe is run through the fitting, heated and shaped to fit the contour of the flange face. Van Stones are usually



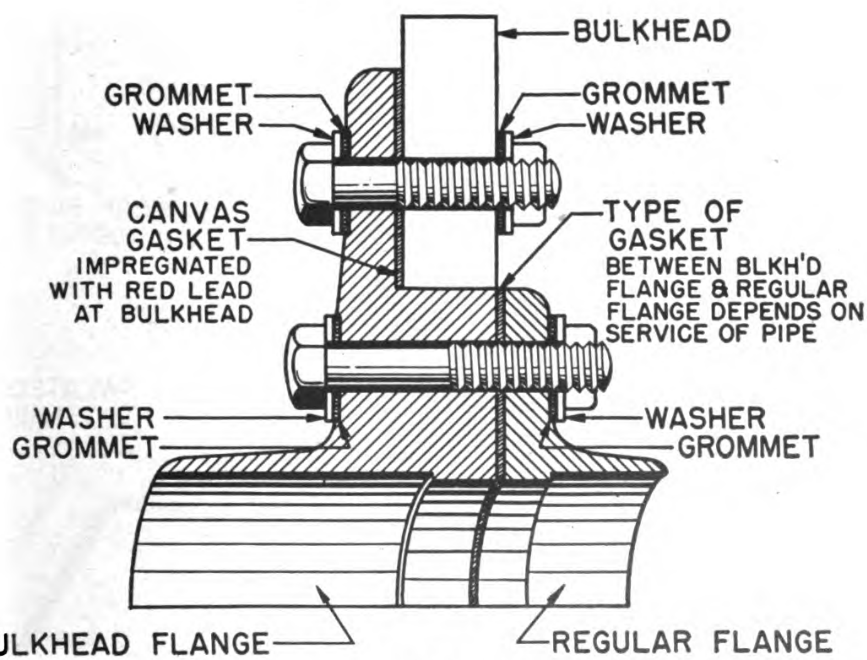


Figure 123.—Bulkhead flange.

made of steel and are used on copper pipe ONLY IN EMERGENCIES. This is because working stresses and vibration tend to crystallize and weaken the copper at the points indicated by the arrows in figure 124.

RIVETED FLANGES are often used on large diameter pipes. Pipe and flange are tinned before assembly and then sweated after assembling, riveting and peening operations are completed.

FLANGE GASKETS

Gaskets for copper pipe flanges are cut from sheet stock which is usually about $\frac{1}{16}$ inch thick. ASBESTOS gaskets are installed for low-pressure steam and general use, PLANT FIBER gaskets for oil and gasoline, and ANNEALED COPPER gaskets for high-pressure lines. Punches, snips, scissors, knives, and rotary gasket cutters are used to cut out gaskets.

REDUCING A PIPE END

The diameter of the end of a copper pipe may be DECREASED by the method used in figure 125. The pounding

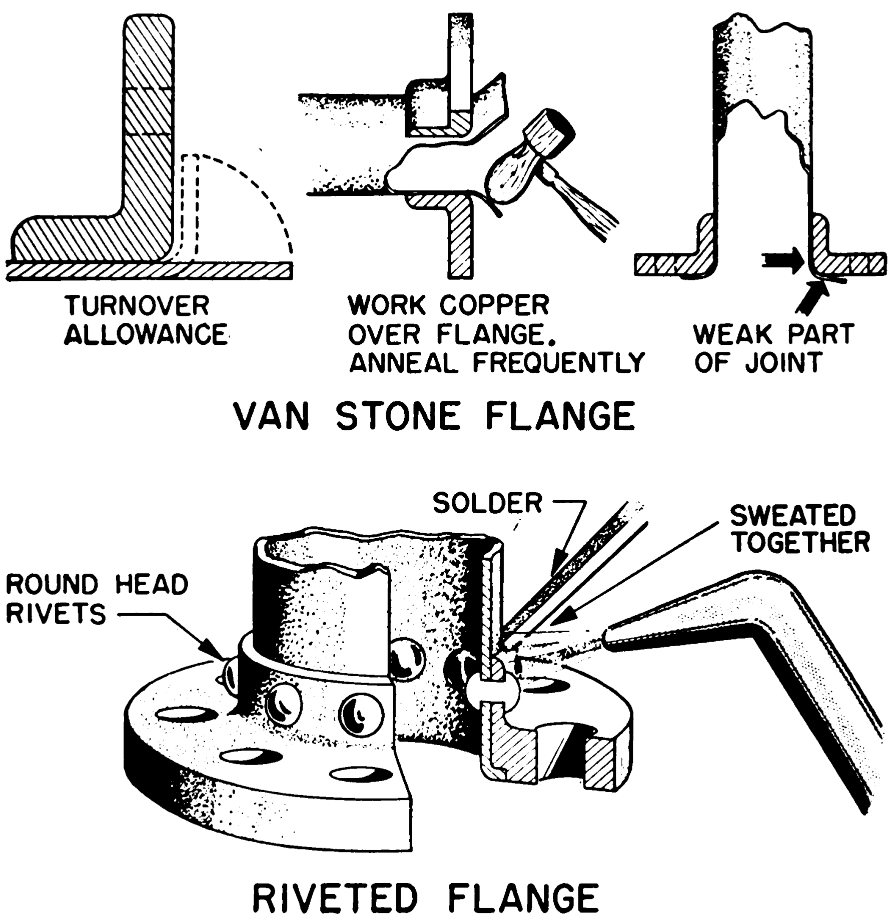


Figure 124.—Van Stone flange and riveted flange.

is done with a wooden mallet while the pipe is held in a grooved wooden block.

Wrinkles are removed as soon as they form by hammering them out after placing over a mandrel or round steel

bar. A swage block may be used for reducing pipes of small diameters.

If the reduction is very great, say from 6 inches down to 3 inches, several annealings are required to prevent cracking. In this reduction from 6 inches to 3 inches, 8 to 10 annealings may be necessary.

MAKING A COPPER CYLINDER

Cylindrical and other shapes are easily made in the shop from sheet copper. If these objects must be formed or

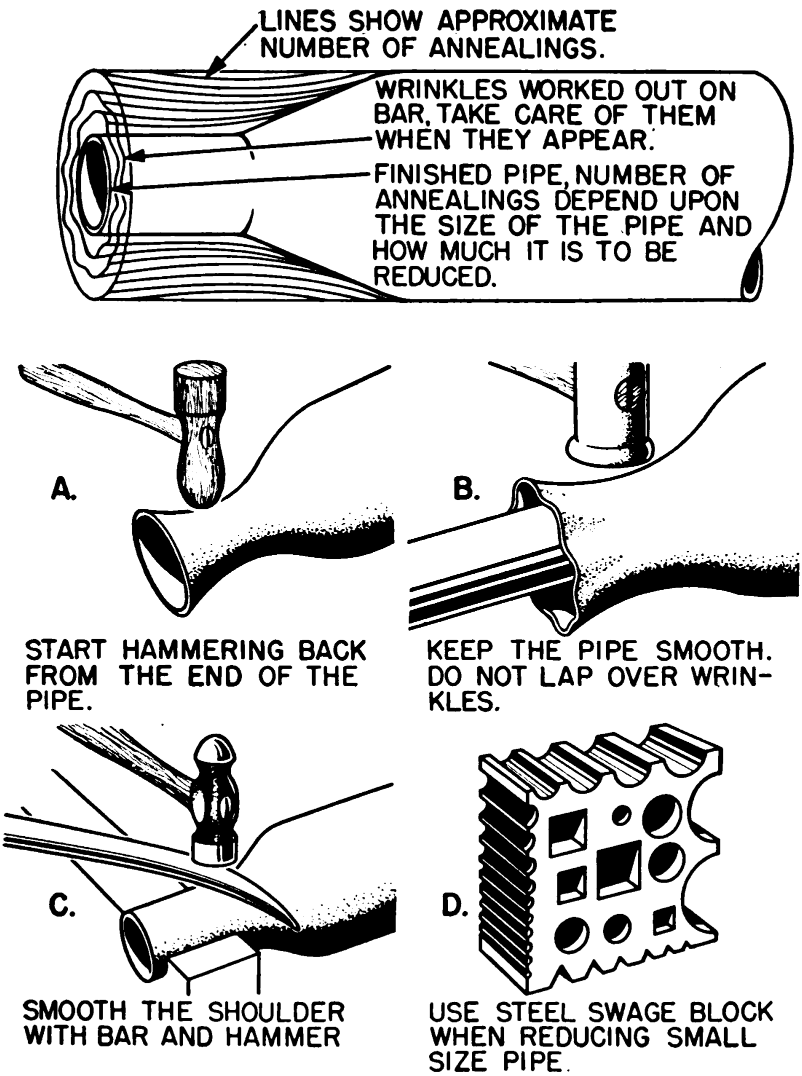
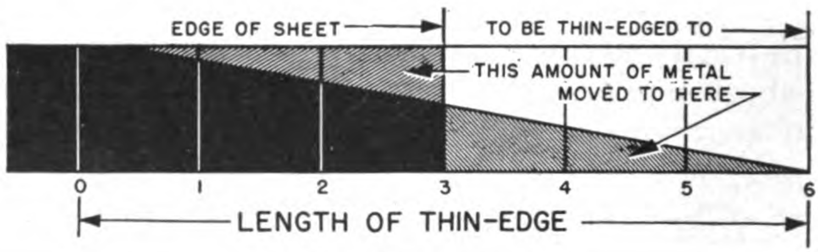


Figure 125.—Reducing a copper pipe end.

bent later on, they are usually spelter-brazed. Silver-brazing is all right if the object DOES NOT require forming or annealing.

Making a cylinder involves considerable **PLANNING**. The **LAP** of the seam is planned first. It should be about 6 times the sheet thickness—measured **AFTER** the sheet is thin-edged. An edge is thinned by hammering it to a taper on an anvil. The allowance for the edge is only ½ of the desired width of the finished edge because the metal is **STRETCHED** when hammered. See figure 126.



THIN-EDGING CHART

SHEET THICKNESS — DECIMALS	SHEET THICKNESS — FRACTIONS	LENGTH OF THIN-EDGE
.032	1/32"	1/4"
.062	1/16"	1/2"
.125	1/8"	3/4"
.1875	3/16"	1 1/8"
.25	1/4"	1 3/16"
.3125	5/16"	1 1/4"
.375	3/8"	1 1/4"

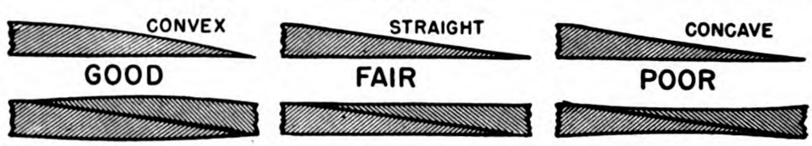


Figure 126.—Thin-edging principles.

Before the metal is rolled, the thin edges are made on opposite sides. A strong seam should be slightly convex when formed, as shown in figure 126. After brazing, the seam is hammered down to approximate sheet thickness.

Spelter-brazed seams are superior because they can be annealed and worked. Silver-brazed seams cannot withstand the heat required for full annealing.

MAKING A COPPER BALL

To make a ball-type float of sheet copper, use the method illustrated in figure 127. Use only a wooden or rawhide mallet for hammering. Butt-seam floats are brazed. Floats exposed to salt water should be tinned all

over, then seamed together and sweated. Bosses are brazed on salt-water floats before assembling and before tinning.

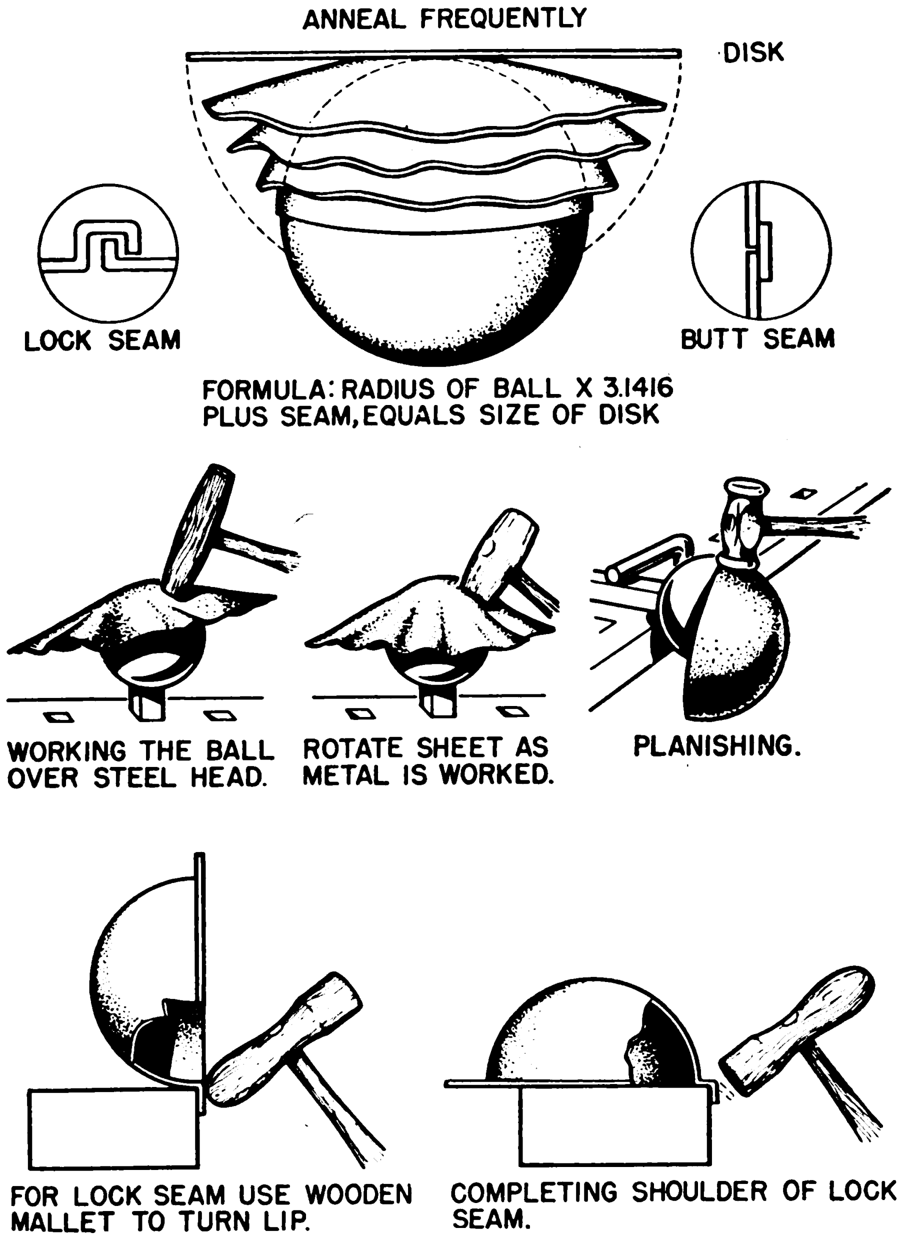


Figure 127.—Making a ball float.

Floats may be tested by submerging them in hot water. Air bubbles indicate a leak.

Some workmen prefer to shape each half of a float by pounding a sheet of copper into a form or mold. This system is OK if you have a mold of the right size and shape or can get a Carpenter's Mate or Machinist's Mate to make you one.

BOSSES

Bosses are small castings made of copper alloys. They are secured to floats and copper pipes by brazing. Bosses have various purposes. In the case of copper pipes, they allow smaller pipes and instruments to be connected in the line.

SURFACE BOSSES (figure 128*A* and *B*) are cut, filed, or ground to fit the contour of the pipe. They are then wired in place over the hole in the pipe and brazed.

CUP BOSSES (figure 128*C*) are imbedded in a cup which is raised on the pipe or in the end of a short saddle branch.

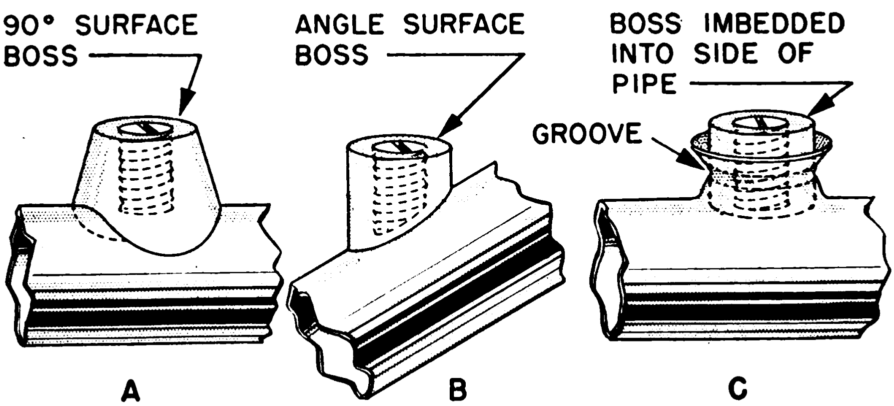


Figure 128.—Bosses.

Note that these bosses are GROOVED. The copper is hammered into this groove so the boss will not slip during brazing.

TEMPLATES AND TARGETS

The patterns made by a Metalsmith for use in making up and fitting pipe sections are called TEMPLATES. They may be made of wood, wire, old tubing, or sheet metal. Adjustable templates are sometimes used.

The wooden template, figure 129, is made up of two wooden flanges, a connecting piece which is cut to fit, and suitable braces. The wooden flanges match the regular flanges.

After the template is fitted, it is taken to the shop and bolted between two TARGETS. Allowance must be made for gasket thickness. The targets are then rigidly secured to the deck and the template is removed. Then the pipe is cut, bent, and flanged to fit between the targets. Notice that the pipe is bent so that both ends are perpendicular

to the flange faces. The bend helps to take care of the expansion and contraction of the pipe.

Don't use force to fit the targets to the template or the pipe to the targets. Easy does it—don't get in a rush.

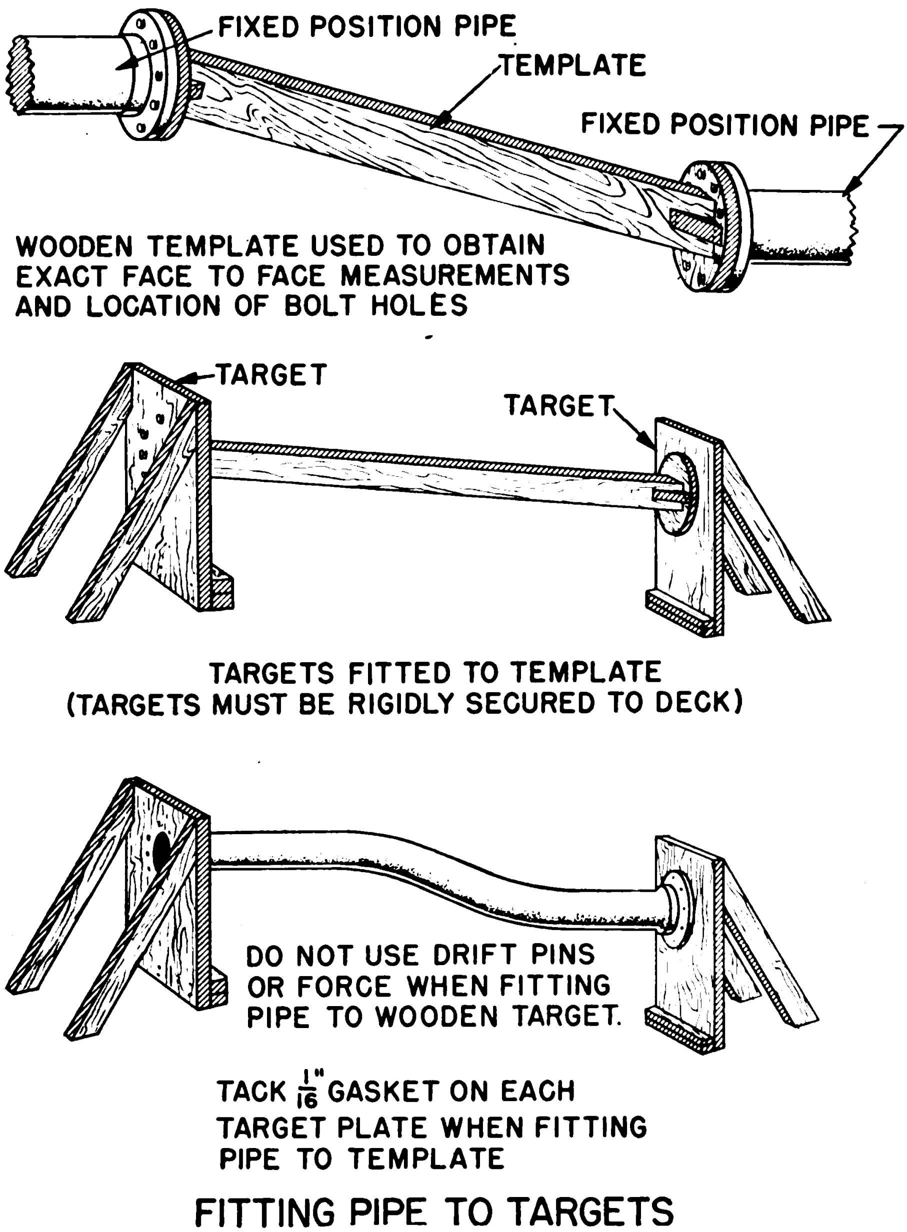


Figure 129.—Templates and targets.

When the pipe is installed it must be a perfect fit—the flanges must be alined exactly and the bolt holes must match precisely.

CENTERLINE templates are made of wire or rod, and shaped to establish the centerline of the pipe to be installed. The ends of the wire or rod are secured to special clamps known as FLANGE SPIDERS. Figure 130 shows the

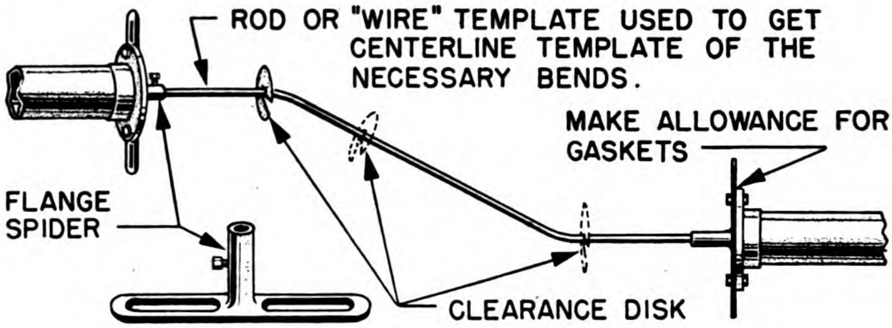


Figure 130.—Centerline template.

set-up. The CLEARANCE DISK is the same diameter as the pipe. This disk is used if there is some doubt about the clearance around the pipe where it's to be installed.

All templates and targets must be handled carefully to prevent distortion and incorrect alinement. Careful han-

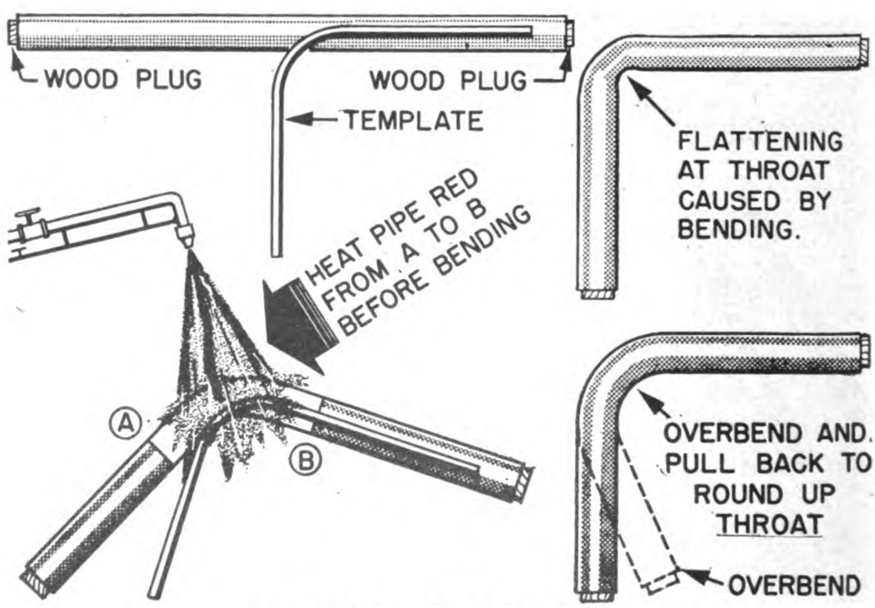


Figure 131.—Sand bending.

dling insures a good fit when the pipe is put in place—it will save you a lot of slow reworking.

PIPE BENDING

THIN-WALL COPPER PIPE or tubing, up to 1½ inches in

diameter, may be bent HOT when packed with DRY sand. One end of the pipe is plugged, the dry sand is tightly packed in the tube, and the other plug inserted. One plug MUST have a hole in it, through which gases may escape when the pipe is heated. The heating and bending process is illustrated in figure 131.

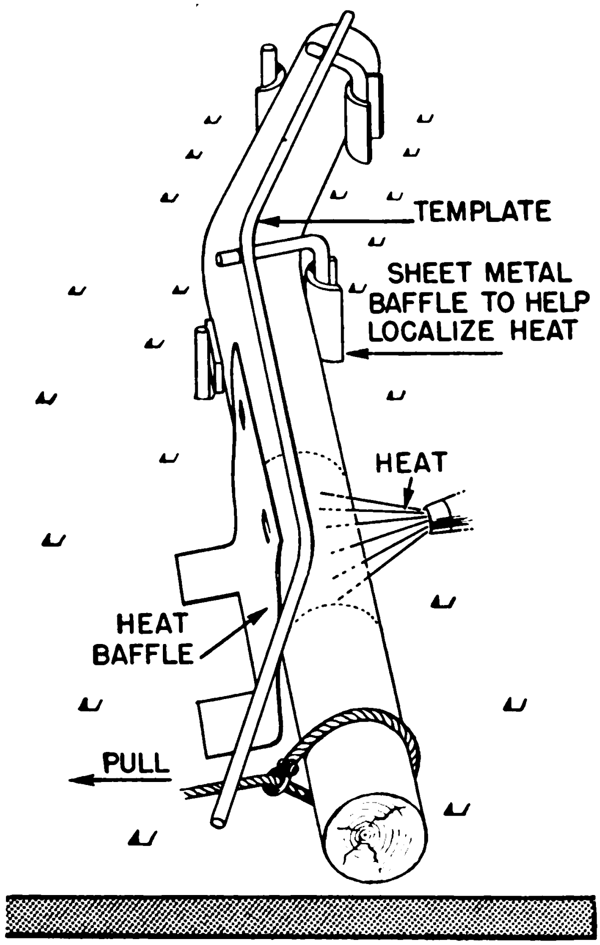


Figure 132.—Sand bending on a slab.

THICK-WALL pipe up to 6 inches in diameter may be handled in the same way. This heavier pipe can be placed on a slab and bent as shown in figure 132.

A pipe of large diameter is annealed, plugged at one end and poured full of MELTED ROSIN while the pipe is still warm. When you're melting rosin for pouring, MELT IT FROM THE TOP DOWN by applying heat with a portable burner. Apply the heat to the top of the container first and move the flame downward as the rosin melts from the top.

AFTER cooling, the pipe is plugged at the open end and

bent COLD. DON'T EVER HEAT A PIPE FOR BENDING WHEN IT IS FILLED WITH ROSIN. An explosion may occur!

After the pipe is bent, the rosin is carefully melted out by inclining the pipe and heating it at the LOWER END FIRST.

Use sand bending (figures 131 and 132) if you can because only one filling is required, and it's not as dangerous as rosin bending. Sand bending is also much faster and cheaper.

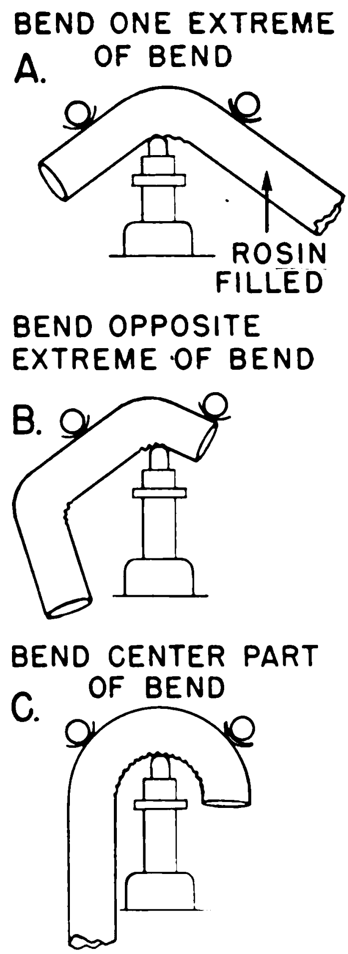


Figure 133.—The return bend.

Use rosin for sharp bends in large diameter copper pipes, but don't expect to do the job in one operation. The pipe will require several annealings, and here's the rub—the rosin must be carefully melted out EACH TIME before annealing.

Rosin bends are formed on a bending press. The steps

in making a horseshoe-shaped RETURN BEND are shown in figure 133. If no press is available, a jack can be mounted on a slab or bench and used as a horizontal press.

WRINKLES?

Sure you'll get wrinkles—plenty of them, and it's a good thing you do. Otherwise the outside of the pipe would be stretched thin. As it is, the inside of the pipe is COMPRESSED to equalize the strain. So you don't want to

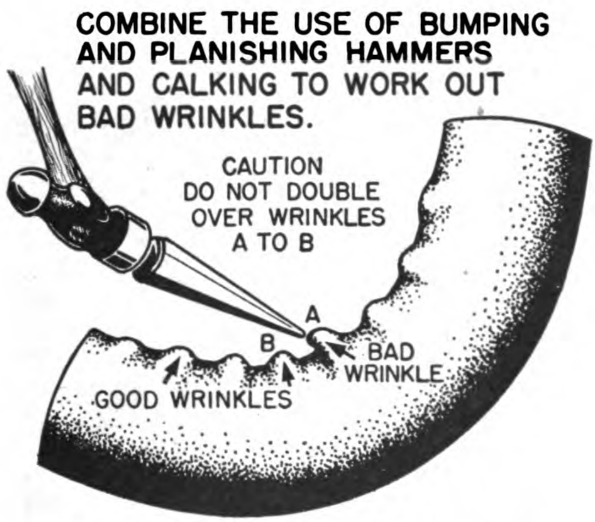


Figure 134.—Working out bad wrinkles.

prevent wrinkles; you just want to CONTROL them. Try to form a bend with a lot of small, evenly-spaced wrinkles, rather than a few large deep ones.

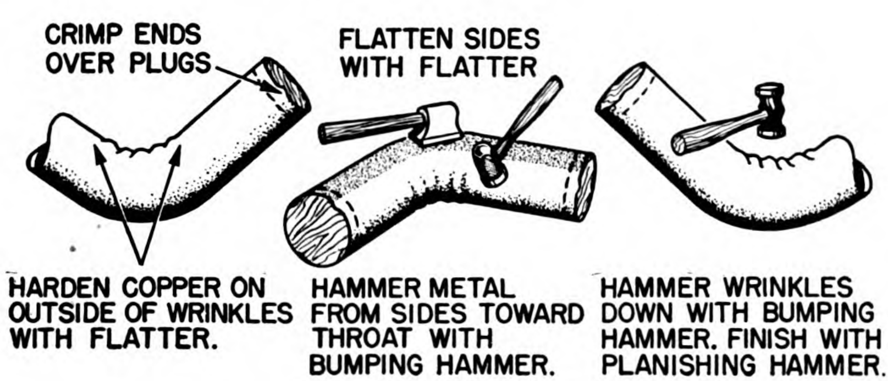


Figure 135.—Smoothing rosin bends.

When you do get a bad wrinkle, work it out with the method pictured in figure 134. A wrinkle should NEVER

be allowed to fold over. If it doubles over, the metal will crease and start a crack.

Wrinkles in rosin bends can be worked down COLD while the rosin is still in the pipe. Make sure the plugs are tight, and then use the method shown in figure 135. The rosin pulverizes as you pound—that's why you can smooth out the wrinkles without taking the rosin out.

Wrinkles in rosin bends of large pipes can be worked out after the rosin is melted out. Notice how it's done with bumping ball and hammer in figure 136.

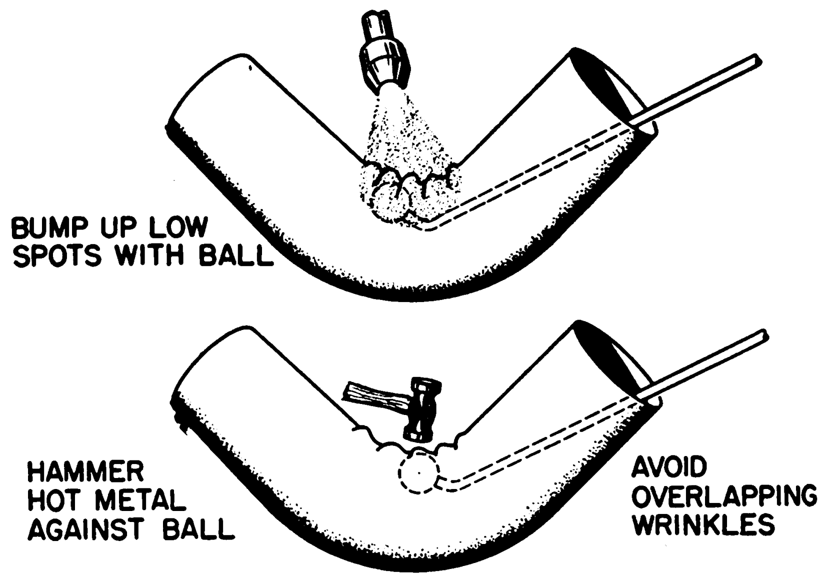


Figure 136.—Hot working the wrinkles.

Be ready to put out a fire at any time when you're heating rosin. If a pot of rosin starts to burn, place the lid on the pot and let the flame smother. It's up to you to have the lid ready.

And remember—rosin will explode when heated in a confined space. Sounds dangerous but you won't have to worry if you—

HEAT THE SIDES FIRST and start at the top, when you're melting a pot of rosin.

REMOVE BOTH PLUGS from a pipe before you start to melt out the rosin.

NEVER apply heat to the MIDDLE of a rosin-filled pipe.

ALWAYS start melting at the lower end of the pipe while it is in an inclined position.

CUP JOINTS

END CUP JOINTS are often used to join the ends of copper pipes and tubes which ordinarily do not require dismantling. The cup joint eliminates the necessity for a flange joint and requires less space.

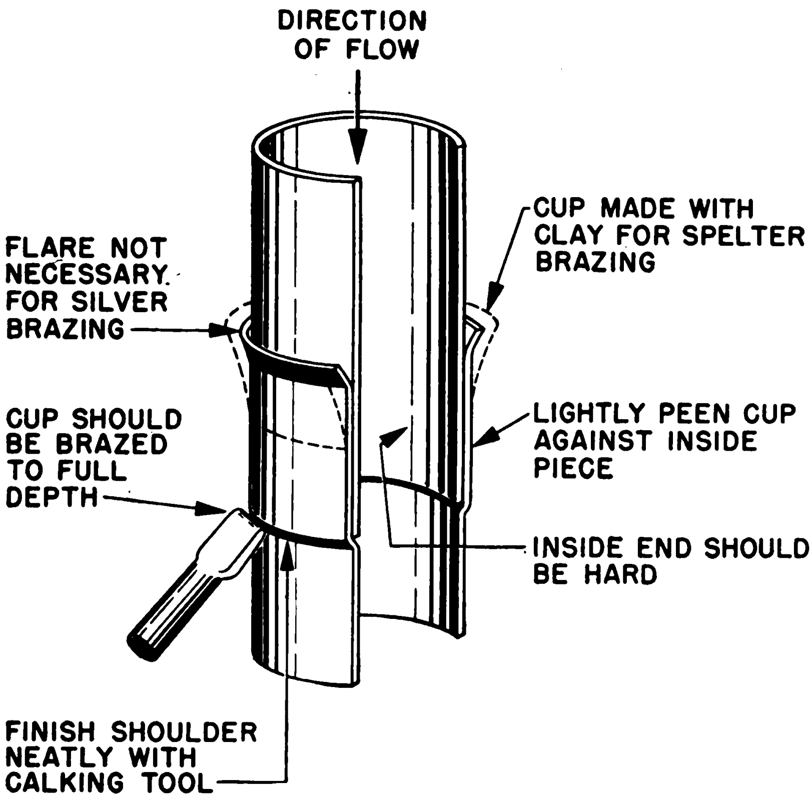


Figure 137.—End cup joint.

Look at figure 137. The cup length, for pipes under five inches, is equal to the pipe diameter. Cups for large diameters are seldom more than eight inches long. The pipe end must be fully annealed before the forming is started and reannealed as required.

The top edge of the cup need not be flared if you braze it with silver solder. Note how the cup is CALKED to fit snugly against the end of the other pipe. If the cup is silver-brazed, it should fit with only .002″ or .003″ clearance.

A CUP BRANCH is used to fit a branch line to a main line. This joint is easy to make by the method shown in the left part of figure 138. Here's how you do it—

Drill a small hole at the center of the intersection. An-

neal the portion to be formed. Work the edge up with a RAISING BAR while the metal is RED HOT. If the sides

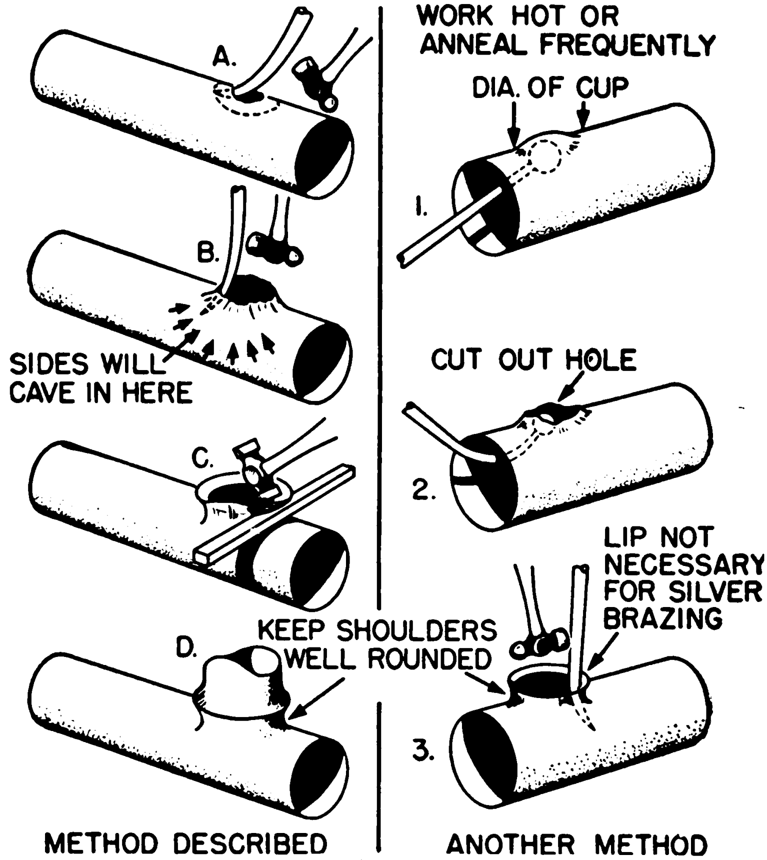


Figure 138.—90° cup branch.

cave in, as in *B*, you can bump them out with a ball.

Shape the cup by the method shown at *C* until it fits snugly around the end of the branch. Then peen the end

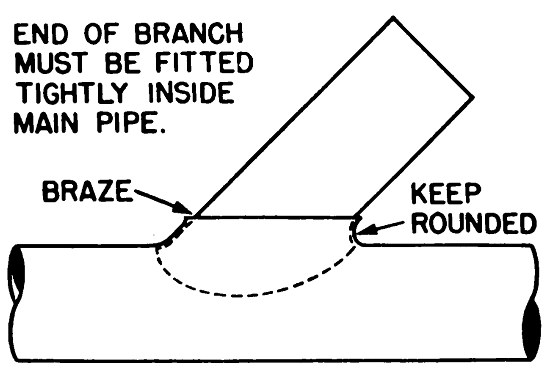


Figure 139.—45° cup branch.

of the branch to fit the cup contour. If you're going to spelter-braze (brass-braze) the joint, you'll have to form

a lip at the top of the cup. Peen the inside after brazing to insure a smooth interior surface that will not disturb the flow of the material in the pipe.

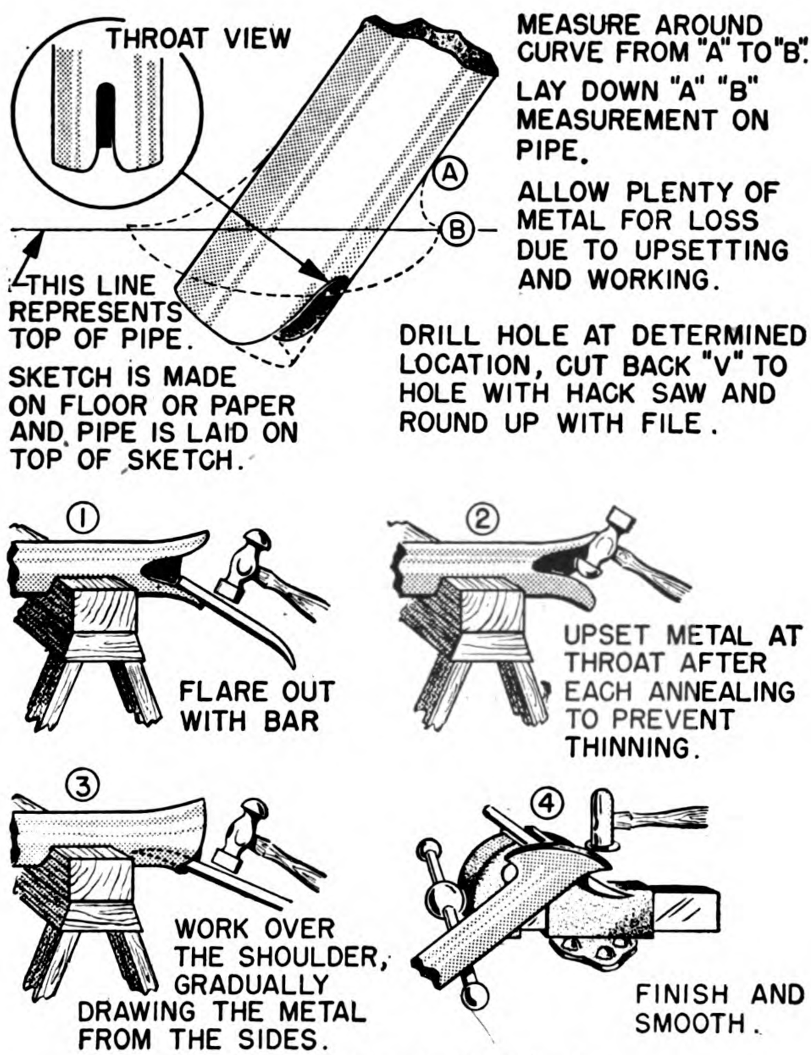


Figure 140A.—Saddle branch.

The 45° cup branch, figure 139, is somewhat more difficult to make than the 90° branch but it's made in much the same manner.

SADDLE AND SWEEP BRANCHES

SADDLE BRANCHES are much stronger than cup branches. To make the saddle, cut and form the end of the branch to fit over the main pipe. Then form the hole in the main pipe by the method used for a cup branch. Next

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shape the end of the branch (as in figure 140A) to form a saddle over the main pipe.

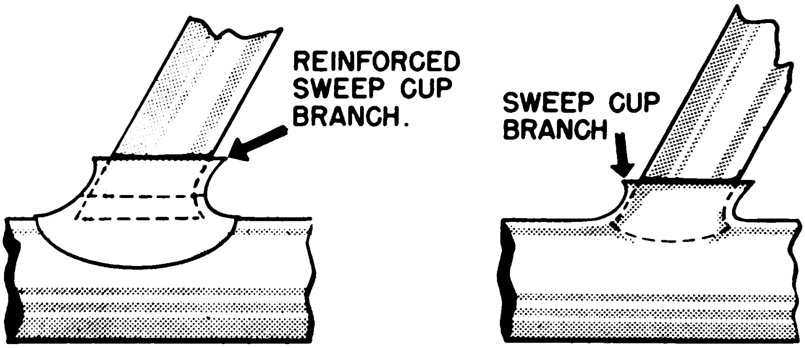

Figure 140*B*.—Sweep branches.

Use the raising bar with a hammer to form the saddle (steps 1, 2, 3, 4). The parts must be fitted snugly or brazing will be difficult.

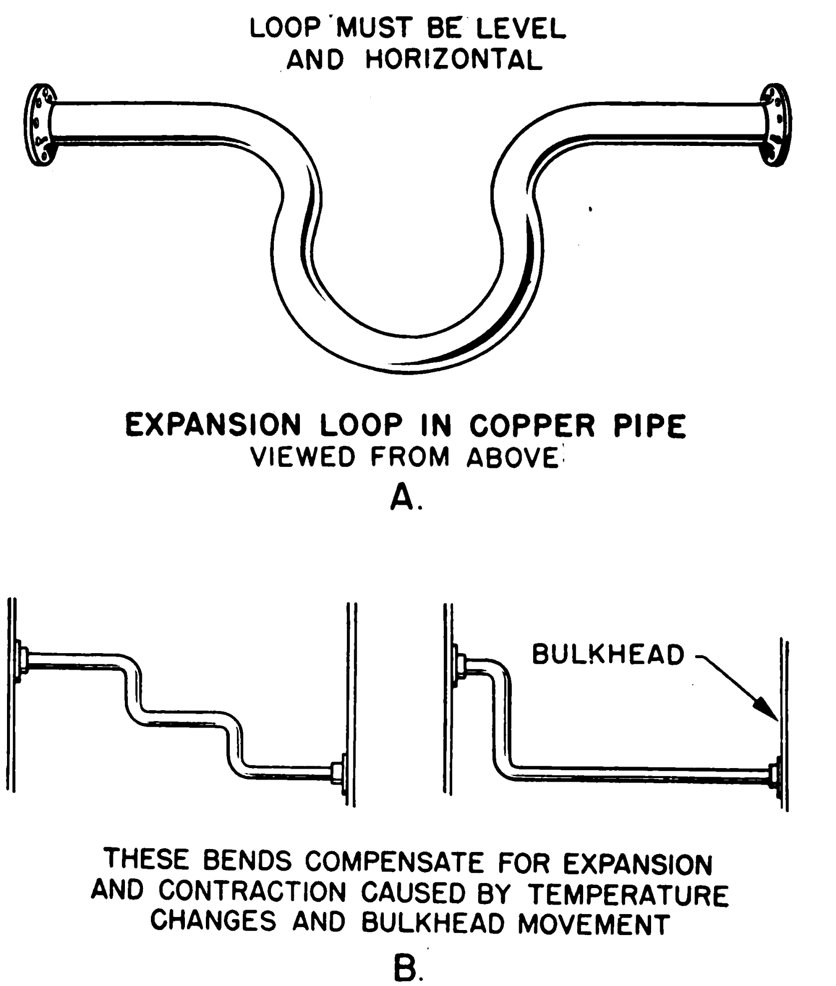

Figure 141.—Expansion loop and bends.

SWEEP BRANCHES (figure 140*B*) are similar to saddles and cup branches except that they CURVE INTO the main pipe. The pipe is bent to the curve before the cup or saddle is formed.

EXPANSION ALLOWANCE

Metals EXPAND and CONTRACT with changes in temperature. A pipe is longer when it is hot; it shortens as it cools. If pipes were rigidly installed, they would soon develop leaks. That's why you see so many BENDS, LOOPS, and BELLOWS in piping systems. These expansion devices also absorb the shock caused by the firing of heavy guns and the bulkhead and deck stresses caused by the pitching of the ship in a storm. They also help the piping to absorb machinery vibration.

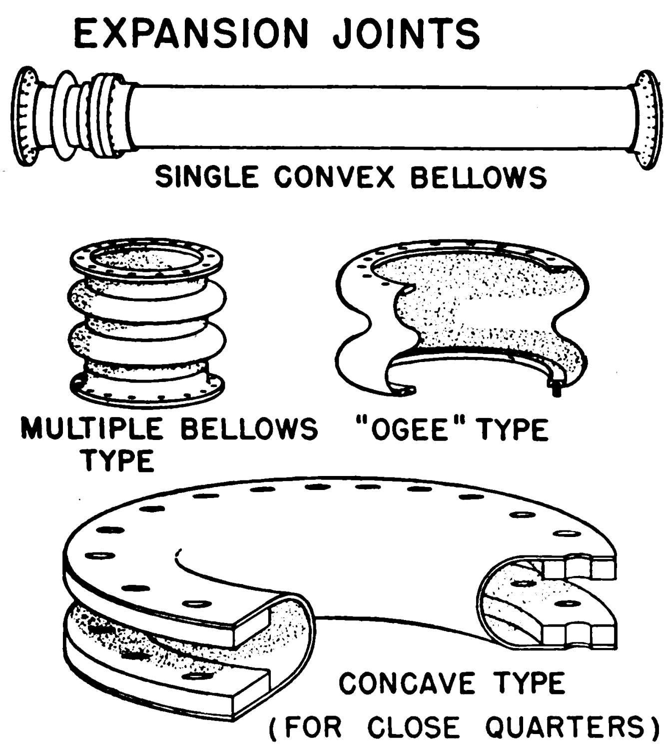

Figure 142.—Expansion joints.

When space and location permit, horseshoe type loops (figure 141*A*) are used in small pipes—in the bilges, for example. To prevent the forming of water pockets, these loops must be HORIZONTAL when used in steam lines. Extra small tubes may have complete loops known as PIGTAILS. On most pipes, the bends shown in figure 141*B* will

absorb the strains caused by vibration, contraction and expansion.

Special EXPANSION JOINTS (figure 142) are "jumped into" a line which cannot be looped or bent. These joints absorb strains because of their bellows construction. CONVEX joints are commonly used. The CONCAVE type is better for short lines, such as are used for pump and engine connections.

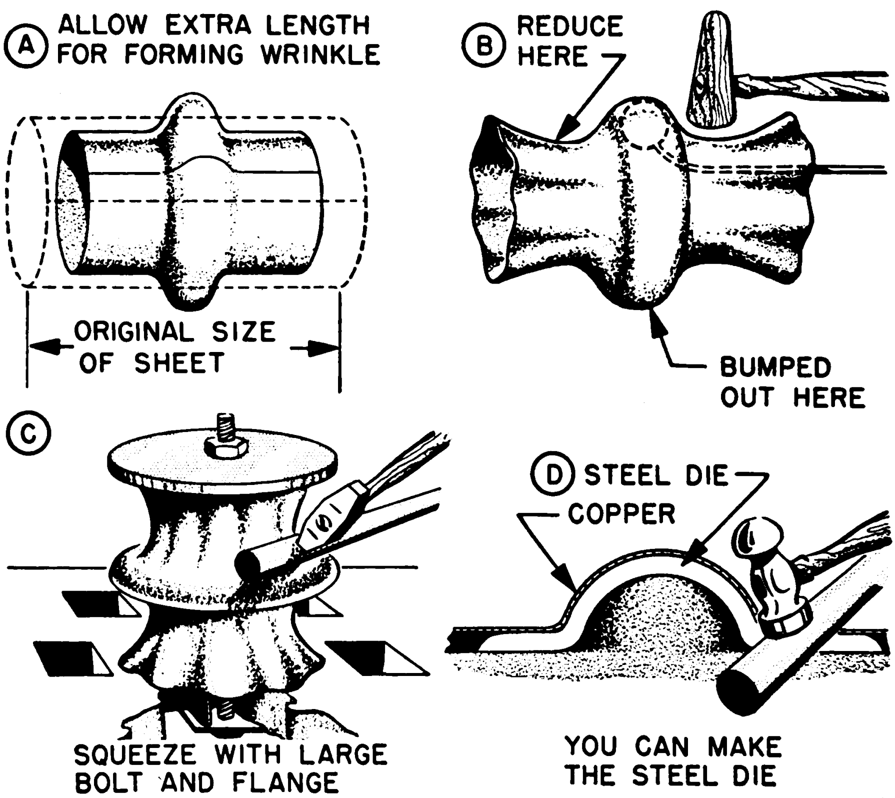

Figure 143.—Forming a convex expansion joint.

You'll usually have spare joints of the required sizes but in an emergency you can make one by the method shown in steps *A*, *B* and *C* of figure 143. Another method is to use a steel die, as indicated in *D*.

RIVETED COPPER SEAMS

Lap seams to be riveted are clamped together, drilled and burred. A few bolts are used as temporary fastenings. The contacting surfaces of the lap are usually tinned before they are riveted. The rivets are also tinned. Look at figure 144. Notice how the rivets are drawn and upset (headed). The joint is sweat-soldered after all rivets are

driven. Some riveted joints are brazed or silver-soldered.

Two rows of rivets (staggered) hold better than a single row. Note that *D* in the lower right view of figure 144, refers to RIVET DIAMETER. This diameter should be about equal to the thickness of the seam (grip).

Countersunk rivets are used ONLY on thick sheets.

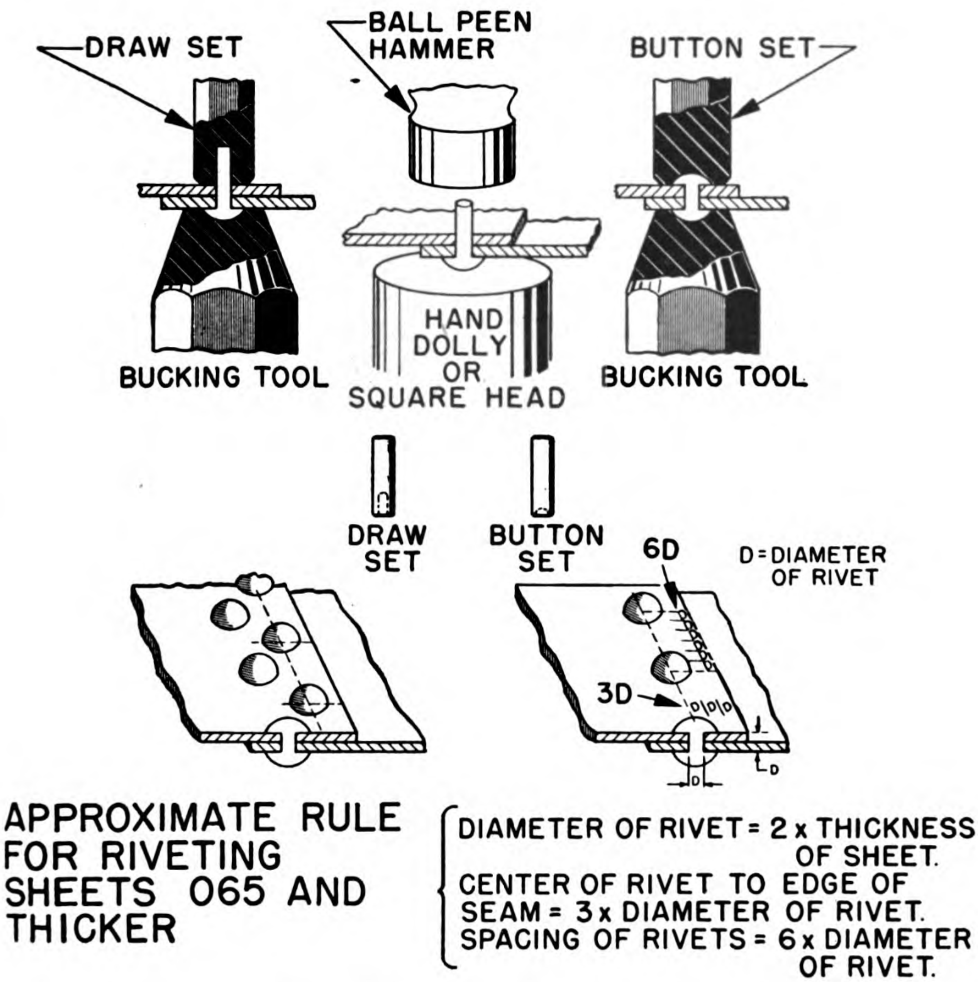

Figure 144.—Riveted copper seam.

PATCHES

Holes in copper pipe may be covered with simple SURFACE PATCHES. The hole is rounded and smoothed and a patch cut to lap at least one inch. The patch is shaped and fitted, then wired in place, and finally brazed with silver solder. These patches are sometimes riveted and then sweat-soldered with soft solder.

A DOVETAILED patch is made as shown in figure 145. This type involves considerable preparation, but it makes a strong, tight patch that is easily brazed.

The dovetails must be cut at an angle and should not extend into the patch any farther than necessary. Note that both hole and patch are THIN-EDGED so the patch will be smooth and flush.

PIPE HANGERS

HANGERS of many shapes and kinds are easily formed of steel. Installation should be such that metal-to-metal

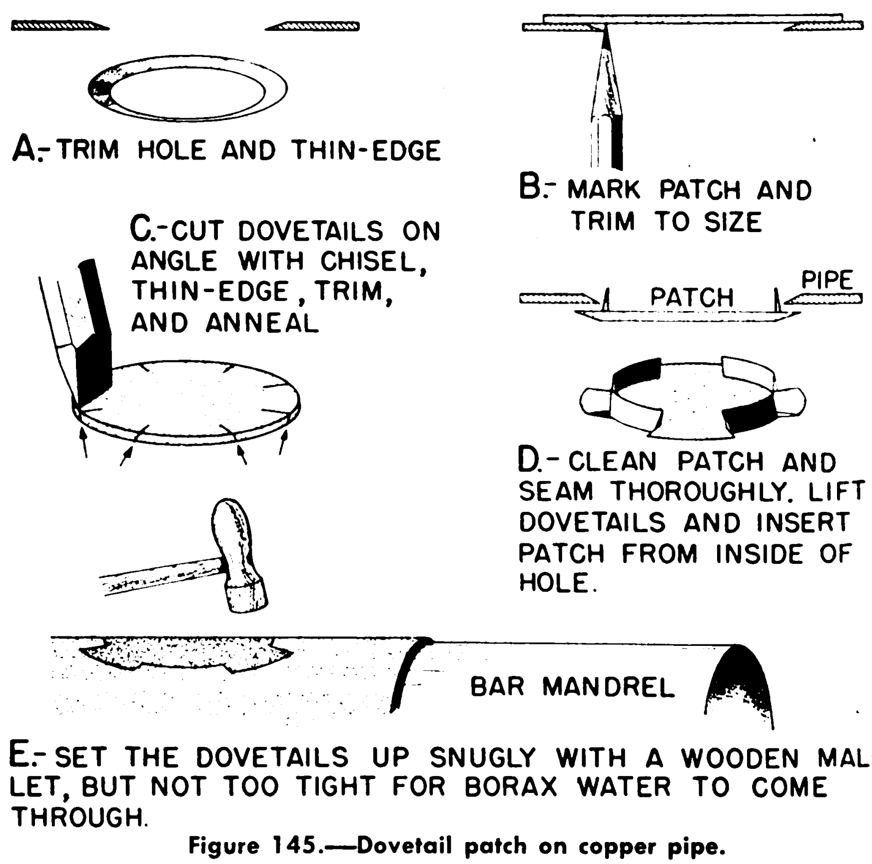

Figure 145.—Dovetail patch on copper pipe.

contact is avoided. Hangers for copper pipe are lined with lead or asbestos packing. Hangers for copper-nickel or tinned pipes are lined with rubber or asbestos. Hangers may also be tinned or galvanized to retard corrosion.

Hanger CLIPS may be welded to beams, bulkheads, and to the overhead, but should NOT be welded to the skin. Hangers are secured to the clips with bolts so that they may be removed and adjusted easily.

WORKING COPPER-NICKEL TUBING

Because it resists galvanic action, tubing made of 70 percent copper and 30 percent nickel (copper-nickel alloy) is used extensively for salt-water lines. This tubing is a silver-white color.

Copper-nickel MUST BE COLD WORKED. Otherwise it's handled the same as copper. The annealing temperature of copper nickel is 1450°F.

Copper-nickel is usually silver-brazed. As this copper-nickel alloy is a poor conductor of heat, preheat the metal uniformly before starting the brazing.

PRESSURE TESTING

Pipe sections that have been made up and flanged are tested with water or air pressure—or both. For the WATER TEST, steel blanks are bolted to the flanges. One blank has a fitting for the water hose or pipe. The other blank has a valve with which you can drain the air from the pipe when the water pressure is applied.

If high pressures are to be applied, a gage is installed in the line so you can determine and control the pressure used. A pipe section is usually tested at 1½ times the working pressure of the system in which it is to be used.

Gasoline, oil, and air lines are often tested with compressed air. The outside of the pipe is coated with soapy water so that leaks will cause bubbles to form. Air pres-

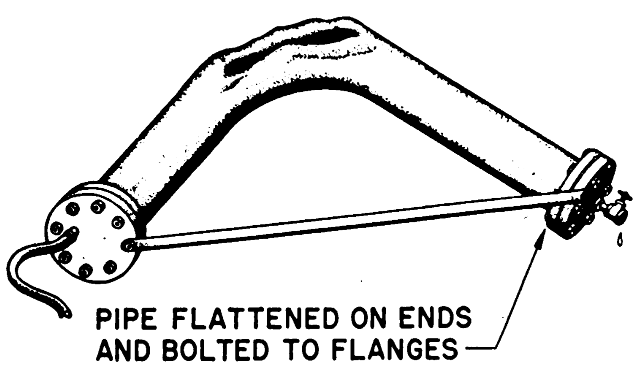

Figure 146.—Removing pipe distortions.

sure tests will show up small leaks which will not show up during the water test.

Special PRECAUTIONS must be taken during an air test to avoid excessive air pressures. If excessive pressures are

used they may burst the pipe, causing metal fragments to fly like shrapnel. Use an air pressure gage and watch it carefully.

WATER-PRESSURE BUMPING

The system known as water-pressure bumping, shown in figure 146, may be used for removing dents and distortions in pipe sections. The set-up is similar to that for water pressure testing.

After the damaged area is annealed, the pipe is put under water pressure and the bumps hammered out with light blows. Dents may be RAISED by lightly hammering the area around the dents.

Notice that a pipe or bar is used to keep the flanges correctly spaced so that the pipe will fit when put back in place.

CHAPTER 10

WORKING WITH STEEL PIPE

HOW PIPE IS MADE

Steel pipe may be of BUTT-WELDED, LAP-WELDED, or SEAMLESS construction. You can tell what type it is by examining a freshly cut pipe. The three kinds are diagramed in figure 147.

BUTT-WELDED PIPE is the least expensive type—but it is also the weakest. This pipe is used ONLY for LOW-PRESSURE steam, liquid, gas, and for electrical conduits. Available sizes range from $\frac{1}{8}$ to 3 inches.

LAP-WELDED pipe is made in sizes ranging from 2 to 6 inches in diameter. It's 20 percent stronger than butt-welded pipe but is not used for high pressure lines.

SEAMLESS pipe is the best and strongest type. It's used for steam and water lines carrying more than 100 pounds pressure. Its best feature is its bending properties—it has no seams to crack or split. Seamless pipe is available in all standard sizes.

Note—The terms "pipe" and "tubing" have the same general meaning. Either term may be used. However, the term "pipe" is generally used when threads are cut for assembly of sections with fittings.

PIPE WALL THICKNESS

The thickness of a pipe wall is often designated commercially as

STD.—Standard
XH.—Extra Heavy
XXH.—DOUBLE Extra Heavy

(The word "strong" is sometimes used instead of "heavy.")

The Navy has set up its own specification symbols for all kinds of steel. The terms "standard," "extra heavy"

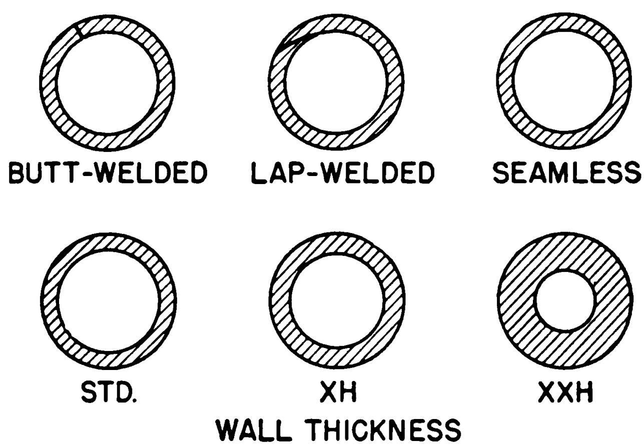

Figure 147.—Steel pipe construction.

and "double extra heavy" are seldom used. Instead you'll see such specification symbols as—

44T43, TYPE B, GR. 1, (2″ MAX.)—Steel pipe specified for fresh water lines carrying 400 lbs. pressure.

44T43, TYPE A, GR. 1.—Steel pipe specified for steam lines carrying 650 lbs. pressure.

The table in figure 148 lists the sizes and wall thicknesses for standard inside diameters, up to 6 inches. The column at the left of this table gives the standard I.P.S. (Iron Pipe Size).

A ship's piping must be stronger and have a higher safety factor than systems used ashore. That's because the ship's piping is subjected to severe strains caused by pitching and rolling, engine vibrations and gun recoils. Also, piping systems must be able to "stand up" in the event of damage as a result of enemy action—shell, bomb, rocket, or torpedo hits.

High-pressure steam lines, fuel oil lines, and water and

fire mains are designed to be unusually strong and tough.

Standard and extra-heavy pipe is either BLACK (untreated) or GALVANIZED (coated with zinc, inside and out.) Double-extra-heavy pipe is NOT galvanized—it is always BLACK. Black pipe is normally used if hot-bending is re-

PIPE WALL THICKNESS

Nominal Size (Inside dia.)	Outside dia.	Standard	Extra-Heavy	Double Extra-Heavy
⅛	0.405	0.068	0.095	..
¼	0.540	0.088	0.119	..
⅜	0.675	0.091	0.126	..
½	0.840	0.109	0.147	0.294
¾	1.050	0.113	0.154	0.308
1	1.315	0.133	0.179	0.358
1¼	1.660	0.140	0.191	0.382
1½	1.900	0.145	0.200	0.400
2	2.375	0.154	0.218	0.436
2½	2.875	0.203	0.276	0.552
3	3.500	0.216	0.300	0.600
3½	4.000	0.226	0.318	0.636
4	4.500	0.237	0.337	0.674
5	5.563	0.258	0.375	0.750
6	6.625	0.280	0.432	0.864

Figure 148.—Pipe wall thickness chart.

quired. Galvanized pipe can be hot-bent but some of its corrosion-resistance is lost as the zinc melts.

When a galvanized pipe is to be welded, the zinc coating should be removed from the weld area. You can do this by heating the area that is to be welded and scratching the zinc off with a wire brush.

PIPE WELDING

Steel pipe is usually WELDED to other steel pipes, to steel flanges, flanged fittings, butt-weld fittings, spools, and sleeves. Steel pipes are often welded directly to the openings in bulkheads and decks. These welds should be made on BOTH sides of the bulkhead or deck.

The CAST-STEEL FLANGE shown in figure 149 is designed for use in lines carrying up to 300 pounds pressure. Still heavier flanges are welded to XXH pipe for pressures ranging up to and above 1,000 pounds.

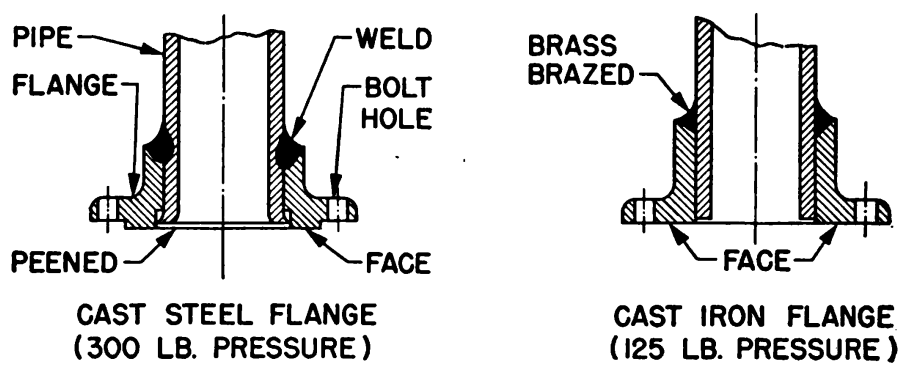

Figure 149.—Pipe flanges.

CAST-IRON FLANGES may be BRAZED (figure 149) to pipes carrying less than 125 pounds pressure. Cast iron flanges

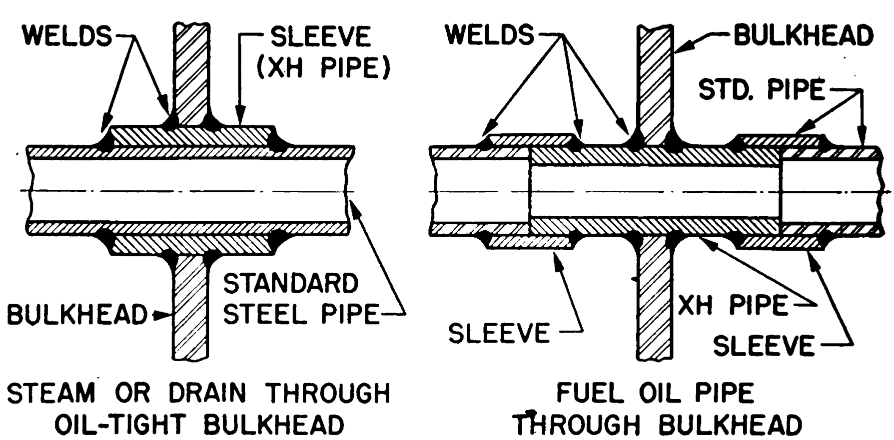

Figure 150.—Piping sleeves.

help to protect a salt-water line from the corrosion caused by galvanic action.

BULKHEAD FLANGES for steel piping are similar to those used with copper and brass piping and tubing.

SPOOLS AND SLEEVES

For some all-welded pipelines which pass through watertight bulkheads and decks, spools and sleeves are used instead of flanged connections.

Two types of SLEEVES are shown in section in figure 150. The sleeves in the left diagram are made of short lengths

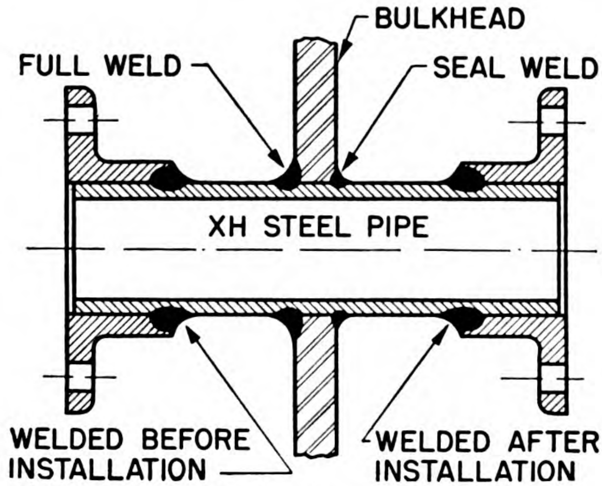

Figure 151.—Bulkhead spool for oil piping.

of XH pipe. In the right diagram, standard pipe is used for the sleeves. If greater strength is needed, use XXH sleeves.

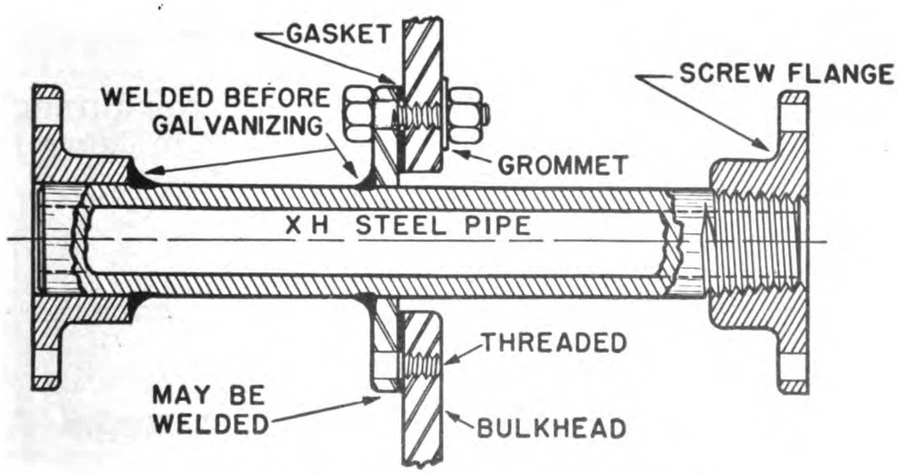

Figure 152.—Spool for galvanized pipe.

A BULKHEAD SPOOL for fuel-oil piping is shown in figure 151. Notice that one flange is welded on before the spool is placed through the bulkhead.

The spool shown in figure 152 is used in salt-water piping. The two welded flanges are put on the spool before it is galvanized. The other flange is THREADED on because welding would destroy the zinc coating.

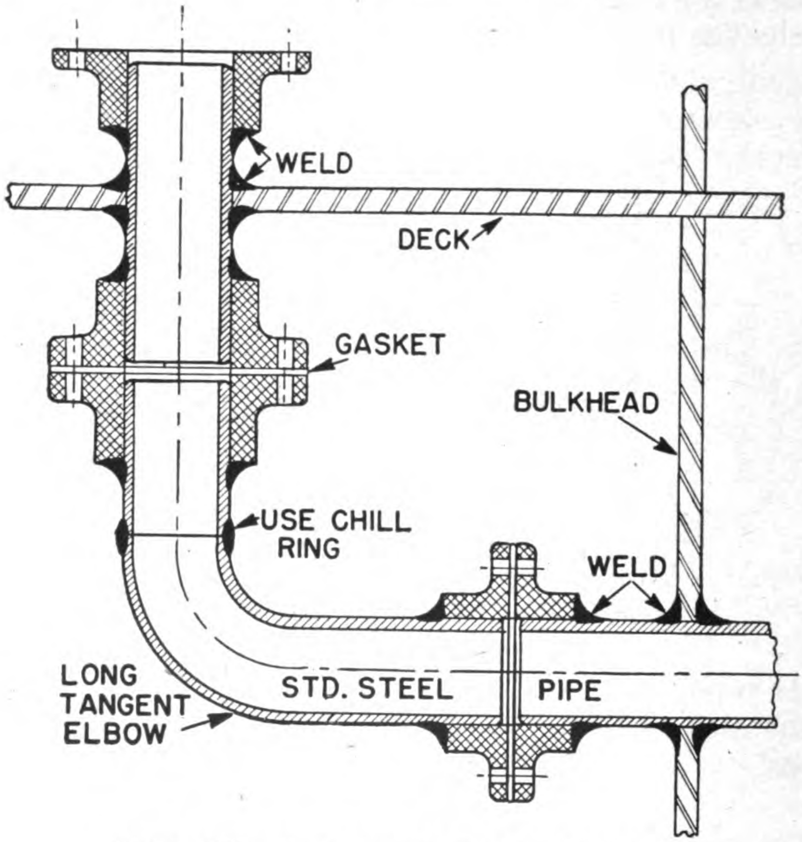

Figure 153.—Line through bulkhead and deck.

One type of connection for piping which goes through a bulkhead and then through a deck is shown in figure 153.

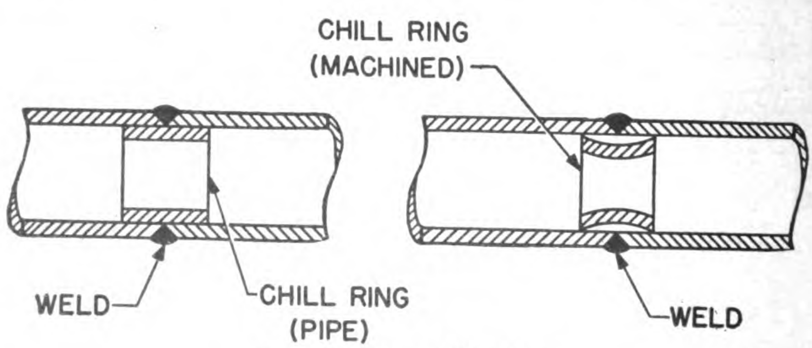

Figure 154.—Chill rings.

CHILL RINGS (figure 154) may be used when pipes are welded end-to-end. Often the ring is just a short length

of pipe. The ring helps to aline the two pipes, backs up the weld, and prevents the formation of weld icicles. Chill rings are left in the pipe unless the flow interference is too great.

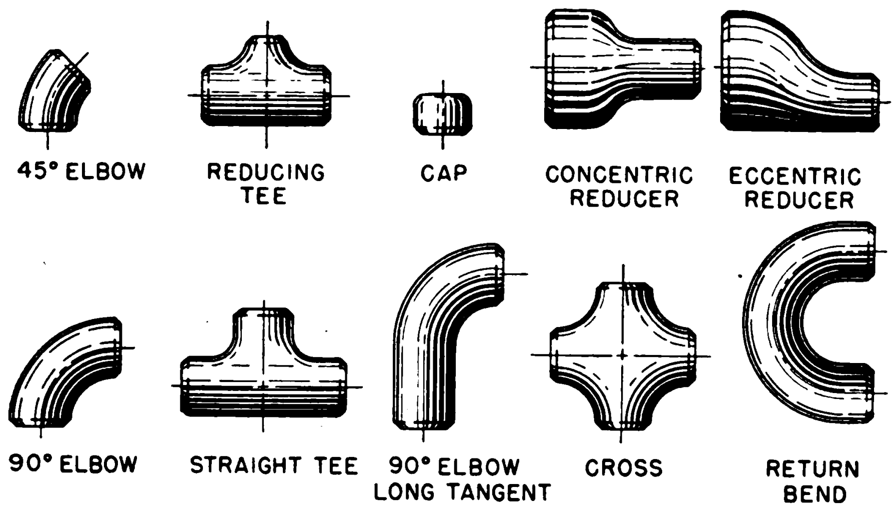

Figure 155.—Forged-steel butt-weld fittings.

WELD FITTINGS

STANDARD weld fittings of the butt-type (figure 155) are "V-ed" or chamfered to assure good welds. These fittings are made of forged steel and perform the same functions as flanged and threaded fittings. Pipe ends must be "V-ed" before being welded to these fittings.

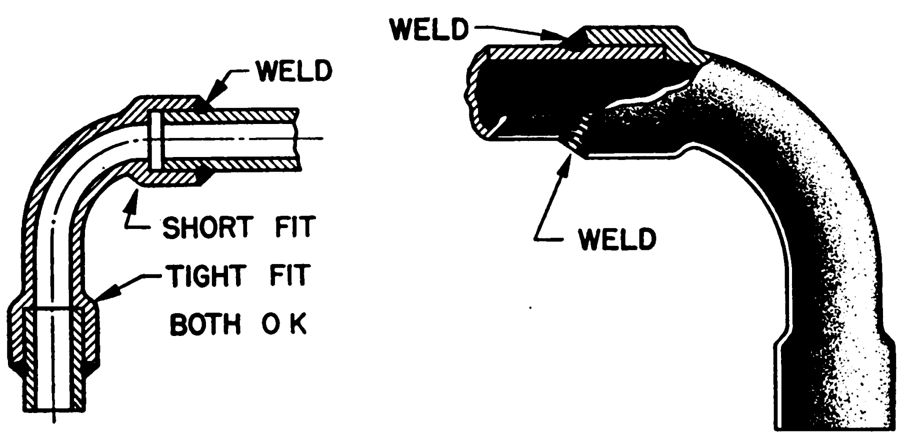

Figure 156.—Socket-weld fittings.

SOCKET-WELD fittings, figure 156, are also made of forged steel. They are used only in small-diameter piping systems. The pipe used in these fittings does not require end-chamfering nor does it have to be cut to exact length.

The joints made with socket fittings are self-alining and are easily welded to form a strong joint. Socket fittings are compact and streamlined—they provide sharp turns without extra bulk and without blocking the flow through the pipe.

PLANNING A BEND

The first thing you do when you are going to bend a pipe is to determine the RADIUS of the bend. A safe radius

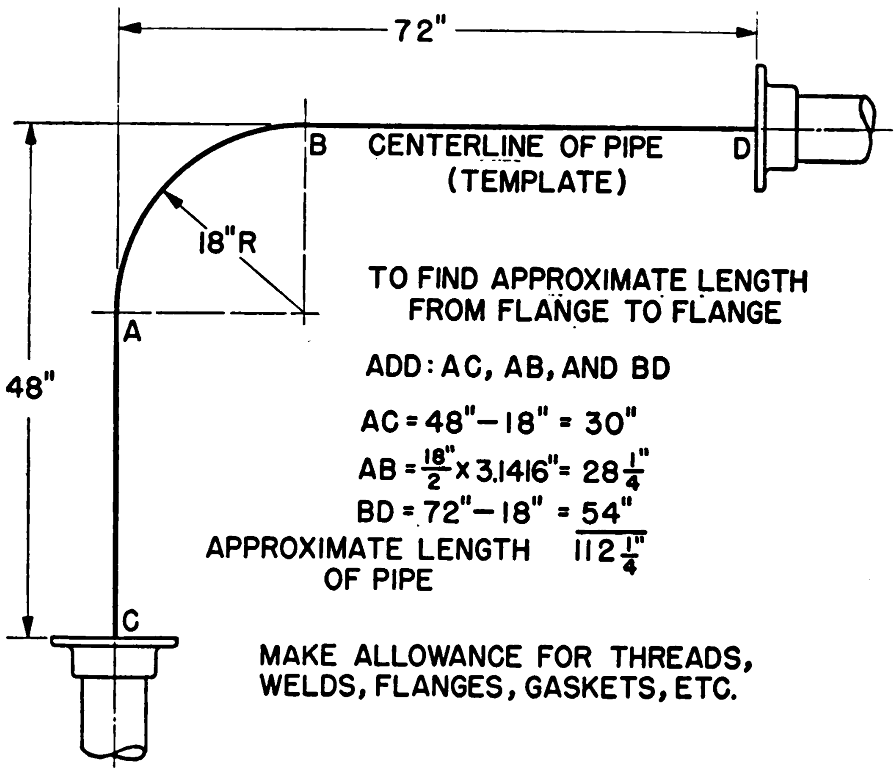

Figure 157.—Figuring approximate length.

is six times the diameter of the pipe. Then determine the approximate length of the pipe by the method shown in figure 157. Don't forget to make the necessary allowances for threads, welds, flanges, and gaskets.

BENDING STEEL PIPE

Pipe 2 inches or more in diameter must be heated before you can bend it; a smaller pipe can be bent cold IF a large bend radius is used. For hot bending the pipe must be packed with DRY sand so the THROAT and HEEL of the bend

will not buckle and flatten. Here's how to prepare to bend a pipe—

Plug one end of the pipe with a wooden plug. (Have some plugs made up in the carpenter shop.)

Fill the pipe with fine DRY sand. BE SURE IT'S DRY. Keep the sand dry by storing it in a warm, dry place.

Pack the sand by tapping the pipe with a heavy wooden mallet. Start tapping at the lower end and work up toward the open end. Add extra sand as required and repeat the tapping process until the sand is packed solidly.

Plug the open end with another wooden plug. Make sure that the plug fits tightly against the sand.

VENT BOTH PLUGS by drilling small holes through them. Place the pipe on the bench and set up your heating apparatus.

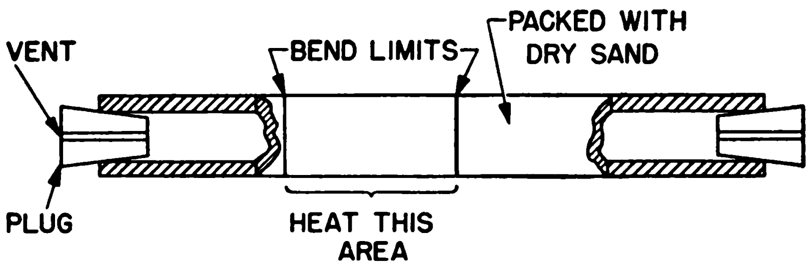

Figure 158.—Pipe ready for bending.

When you have completed these steps, the pipe is ready to be heated and bent. See figure 158. The portion to be bent is marked at both ends with soapstone and brought to a uniform red heat. You can obtain a uniform heat by "playing" the flame over the marked area.

Portable oil-burning or welding torches may be used to provide the heat. Use a torch that burns fuel oil or Diesel oil when you can. These fuels are a great deal more economical than acetylene.

When the pipe is red-hot, bend it to the template by any available means—in the vise, around a stanchion, or in some other way. A simple method is to slip lengths of pipe over both ends of the pipe being bent. Even large pipes may be handled in this way. If one end of the pipe can be secured, the other end can be pulled around with a block-and-tackle. Check the plugs frequently during the bending process.

OVERBEND the pipe—bend it a few degrees past the de-

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sired angle—and then bend it back. See figure 159. This little trick will take the flatness out of the THROAT (inside) and HEEL (outside) of the bend.

If the pipe has a seam (lap-welded or butt-welded pipe), the seam should be INSIDE the bend. The seam is not centered but is located as marked in figure 159.

FLANGED-JOINT GASKETS

Packing or sealing gaskets are placed between flanges to insure the tightness of joints. Steel pipe flange gaskets are made of a variety of materials for various uses. The usual thickness is about $\frac{1}{16}$ inch.

METALLIC gaskets are used in high-pressure and high-temperature steam lines and in hot air lines. These gas-

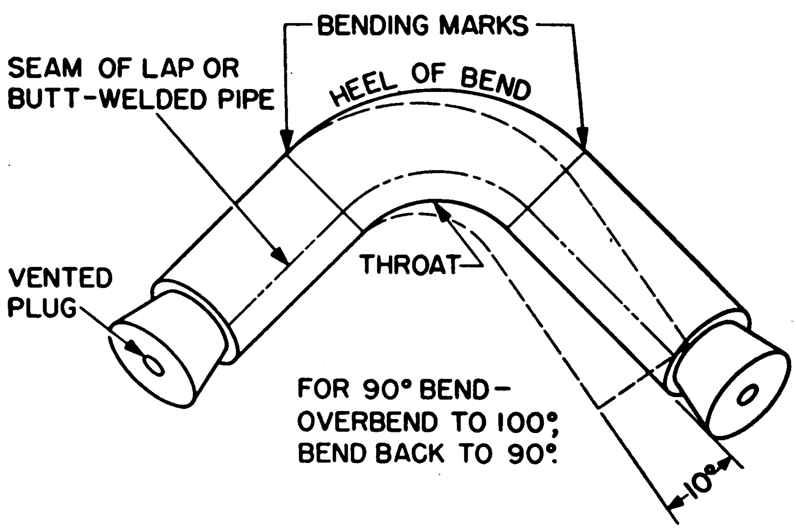

Figure 159.—Overbending.

kets are usually made of soft copper. The copper shapes itself to the flange faces and will not burn out.

COMPRESSED ASBESTOS gaskets are used in low-pressure steam, exhaust, and oil lines.

RUBBER gaskets are used in water lines for packing pumps, valves, manifolds and flanges. They are also used in cold air lines.

CANVAS gaskets, soaked in raw linseed oil and coated with red lead, are used with bulkhead flanges.

PIPE COVERING

Insulation covering is installed on piping primarily to retain heat or cold in the pipe. Some piping is covered

merely to prevent "sweating"—condensation of moisture on the outside of piping. Covering on hot pipes also prevents accidental burns to personnel.

The covering should be as nearly fireproof as possible. The usual insulation is made up of molded sections of MAGNESIA and ASBESTOS FIBER. These sections are cut and fitted and wired in place. Joints and cracks are "mudded up" with asbestos cement. The whole job is then covered with fire-resistant canvas lagging, which is sewed in place.

FIBROUS GLASS is now used extensively as insulating material for some shipboard installations. It is light in weight and is fireproof and vermin proof.

Machinist's Mates and Boilermakers do most of the pipe insulation work aboard ship.

PIPE TESTING

Sections of pipe which have been bent and flanged, and those which have been removed and repaired, are HYDROSTATICALLY tested in the shop. For a test of this type, the pipe is closed with blank flanges and filled with water. The hydrostatic tester, made up of a pressure gage and an air control valve, is connected through one blank flange. The desired air pressure is then applied through the testing set-up.

Steam pipes and water mains are usually hydrostatically tested. Machinist's Mates and Water Tenders normally do the testing. You will repair any flaw which might be found in the pipe section.

CHAPTER 11

FORGING

YOU'RE ALSO A BLACKSMITH

When occasion demands, the Metalsmith becomes the blacksmith of the Navy. Therefore, you must know simple forging procedures. One of the best ways to learn is by helping an experienced workman. Observe how he handles the forging fire, heats the metal, hammers it into shape, and heat-treats it.

Just what is forging? It's the name usually applied to a method of working and shaping metals while they are hot enough to be plastic. Another name for forging is "hot-working." The forging process, when properly carried out, does not damage the metal; in fact, it actually improves its properties. The grain structure of steel is refined by forging—the grains of the metal are broken up to form a strong, fine-grain structure.

While many different metals may be successfully shaped by forging, most of your work will be with the FERROUS metals—wrought iron; low-, medium-, and high-carbon steels; and special tool and alloy steels.

Wrought iron is forged into chain links, hooks, and other small fittings. It is readily forged and has good properties of shock and corrosion resistance. Wrought

iron is seldom cold-worked. It cannot be hardened by heat treatment. Due to the development of alloy steels and gas and arc welding, wrought iron is not used as much by the Navy as formerly. That's one reason the old Navy rate of Blacksmith has been abolished.

STEEL FORGINGS are used extensively in the manufacture of ship fittings, machinery, and other shipboard gear. Most of YOUR forging will be the making of small parts and fittings and shop tools, jigs, and gages. For such work you'll use low-carbon steel—steel containing about 0.25 percent of carbon. Ordinarily you won't have the heavy, expensive, and elaborate equipment necessary for forging large pieces. The forging process is usually followed by some type of heat treatment.

FORGING TEMPERATURES

Steel is forged at temperatures that are well above the critical range but are also well below the melting point.

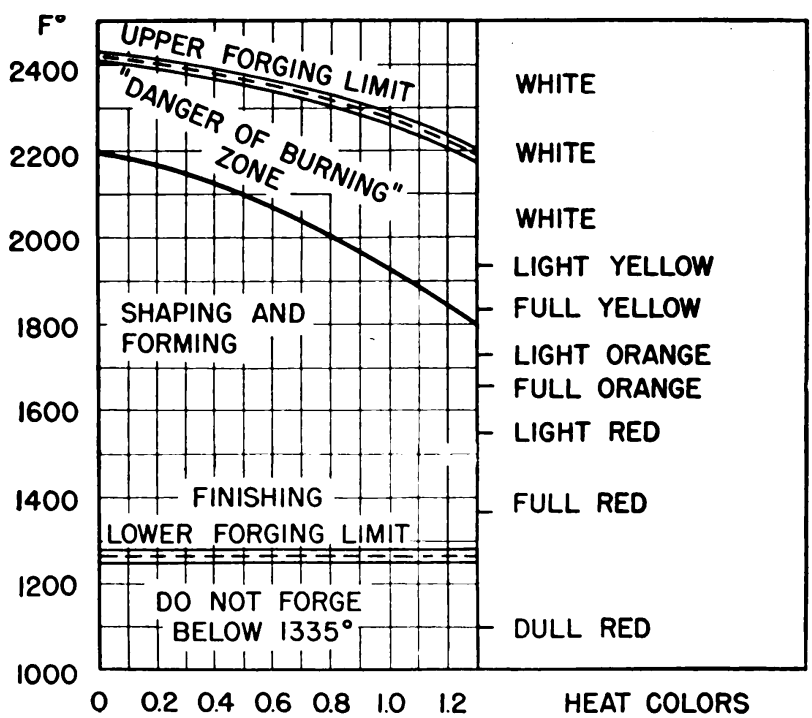

Figure 160.—Forging temperatures for steel.

You may not have temperature-measuring equipment—so learn to judge temperatures by the colors of the hot iron or steel. Use figure 160 as a guide.

The metal must be HEATED UNIFORMLY—all parts should be the same temperature all the way through the metal. When steel assumes a FULL YELLOW color (see figure 160) it is ready to be forged. You can continue forging until the color changed to a FULL RED. The final forging blows are struck at this point and continued until the full red color just begins to change to a DULL RED. If the forg-

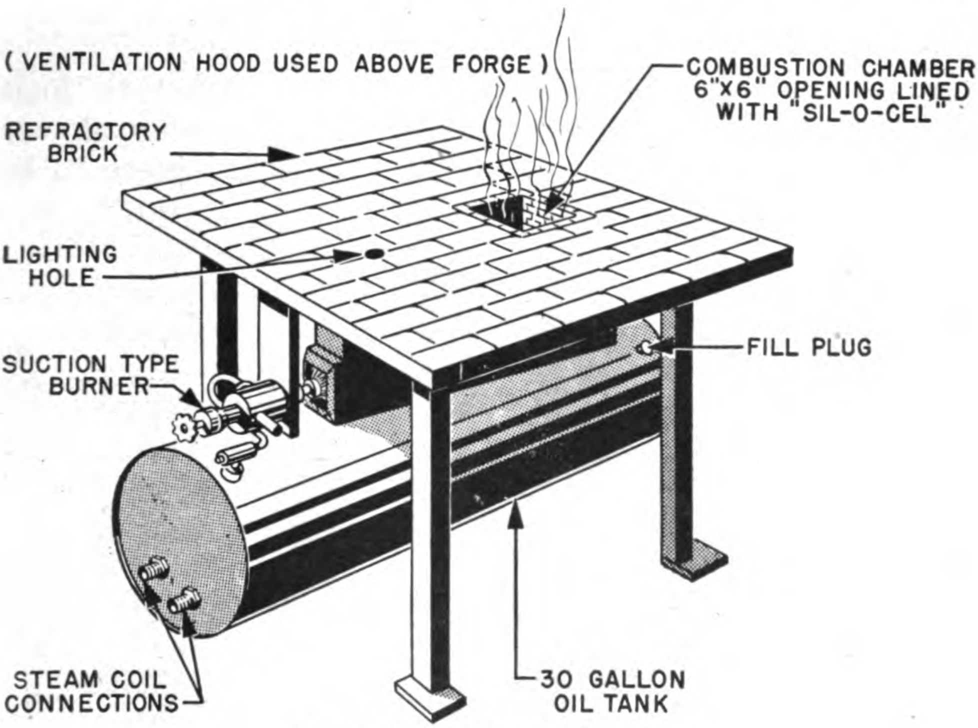

Figure 161.—Oil-burning forge.

ing is not completed at the lower temperature, the structure of the steel will be weakened—the grains will "grow" to larger size.

Wrought iron may be forged at the temperatures indicated for steel which contains less than 0.10 percent carbon.

HEATING METHODS

If you do much forging, you will use an oil-burning FORGE. One of these, of the type used on some cruisers, is shown in figure 161. The AIR and OIL supplies of this forge are controlled with hand valves. In starting the forge, always open the air valve first to give the burner a little air. Then apply a light, preferably a piece of lighted waste. When you have the light in place, crack the oil

valve and continue opening it until it catches and you have the flame burning.

After a few minutes, turn on more air. The flame will turn into a roaring blast of heat that is almost colorless. Your goal with an oil-burning forge is to have a flame that is CLEAR and SMOKELESS. A lot of black smoke means that you are using too much oil.

When you want to stop or shut off the burner, always TURN OFF THE OIL FIRST. Then turn off the air.

Heat-treating furnaces are sometimes used to heat metal for forging. These furnaces are somewhat slower than the oil-burning forge. Also, ALL of the piece to be

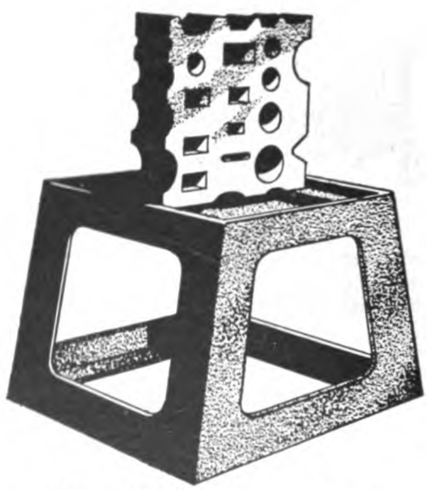

Figure 162.—Swage block.

forged must be heated, which may be a disadvantage. When using a furnace, you can heat only the area which is to be forged.

You can heat small pieces of metal with your oxyacetylene welding torch. Just play the flame over the metal in such a way that the portion to be forged is uniformly heated.

YOUR FORGING TOOLS

Many of the special forging tools you will use—anvils, hammers, sledges, tongs, fullers, and swages—are described and pictured in Chapter 13 of the *Use of Tools* book. You may also have a SWAGE BLOCK, like the one in figure 162. This block is useful for forming all kinds of

shapes. Made of cast iron or cast steel, the block weighs about 150 pounds.

You may also have a special blacksmith's SURFACE PLATE, which has a smooth, leveled face. It's used to test the surfaces and shapes of forged pieces.

FORGING PRACTICE

Here are some important items for you to consider and remember when you are doing forge work—

- CONTROL THE HEATING so that it is uniform over the entire area to be forged.
- AVOID OVERHEATING the metal—watch those heat colors.
- FORGE WITH AS FEW BLOWS as possible.
- PLAN YOUR WORK so that the finishing blows are applied as the steel begins to lose full color.
- AVOID REPEATED REHEATING of the metal. Try to do all the forging with one heat. Repeated reheating will enlarge the grain and weaken the structure.
- QUENCH as soon as the last forging blow is struck.
- KEEP HAMMER HANDLES TIGHTLY WEDGED so the heads won't fly off. The handles loosen because the heat shrinks the wood.
- MAKE SURE THE FORGE FIRE IS OUT before you knock off work.
- HAVE PLENTY OF RESPECT FOR HOT METAL. Wear special leather clothing if you do much forging work.

FORGING OPERATIONS

When heated to the proper forging temperature, steel and soft iron can be hammered into almost any desired shape. The various hammering operations are known as DRAWING, UPSETTING, BENDING, and WELDING.

DRAWING is a method of working a piece of metal so as to increase its length or width, or both, and to reduce its cross section. When both length and width are to be increased, the metal is hammered over the flat face of the anvil. Length only is increased by hammering the metal over the anvil horn, as shown in figure 163. The horn acts as a blunt wedge to spread the metal and force it lengthwise. Pullers can be used in the same way.

Round stock may be drawn out or pointed by the method shown in figure 164. Forge it square first, then octagonal, and then round again. And remember to forge it with as few blows as possible. Try to do all the forging without reheating.

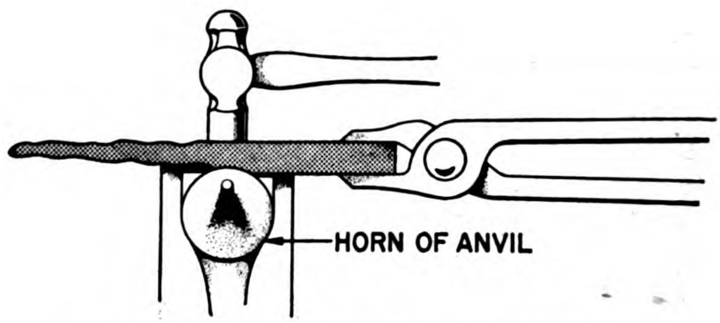

Figure 163.—Increasing length by forging.

UPSETTING is the reverse of drawing—that is, the length is decreased and the cross section is increased. A somewhat higher temperature is required for upsetting than for drawing. The temperature must be near the upper forging limit, as shown in figure 160.

A SHORT piece of steel is upset easily by placing it on the anvil and striking it with a hammer or sledge. Longer

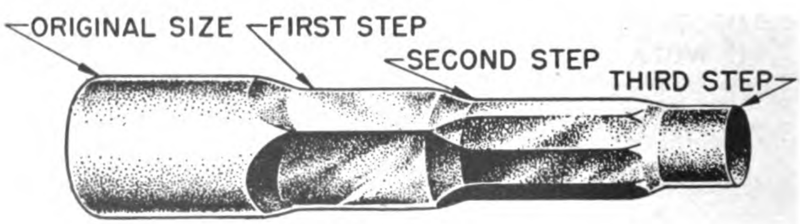

Figure 164.—Drawing round stock.

pieces must be held with tongs. When a long piece bends while it is being upset, it should be straightened immediately. Only the portion of the metal to be upset is heated. The upsetting may be done by any of the methods shown in figure 165.

SHOULDERING (figure 165) is usually accomplished by the upsetting method. It may be done by drawing, also. Upset shoulders are generally formed with a heading tool or by means of one of the openings of the swage block. Drawn shoulders are nicked with a hot chisel to the depth

of the offset and the small end is then drawn in the usual manner.

HOT BENDING

SQUARE and ANGLE bends may be formed over an edge of the anvil face as shown in figure 166. The metal is held down by a helper with a heavy sledge. Notice that

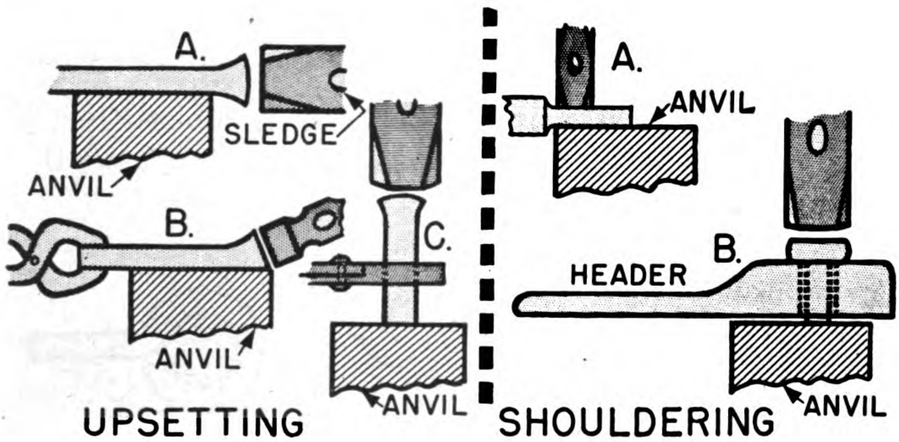

Figure 165.—Upsetting and shouldering.

the bend is started at the end of the piece and not at the point of bend. The bend may be finished square inside and out, or rounded. If an inside radius is desired, the metal is bent over a rounded corner of the anvil or over a stake.

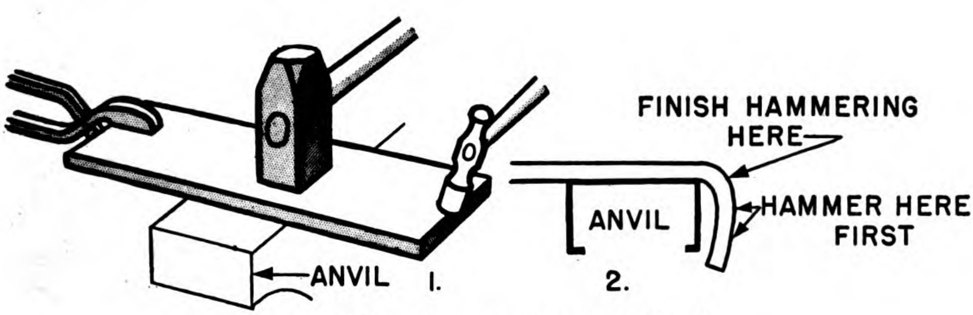

Figure 166.—Square and angle bends.

An angle bend will be stronger if the area of the portion to be bent is enlarged by upsetting. To upset the rod or bar, just heat it at the point of bend and strike one end against the deck. Then bend the rod or bar to the desired angle, using the extra metal to reinforce the bend.

CURVED BENDS are started over the rounded anvil horn

(figure 167.) Notice that the curve is started at the END of the piece. Rings are also forged in this manner.

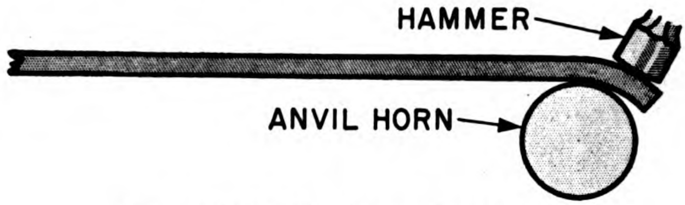

Figure 167.—Starting a curved bend.

One method of bending an EYE on the end of a rod is illustrated step-by-step in figure 168. It looks easy, but you'll have some trouble keeping the curves smooth at first.

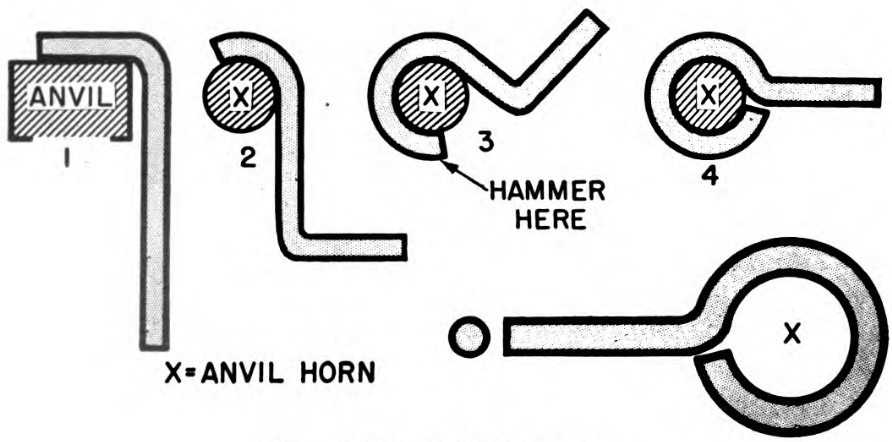

Figure 168.—Bending an eye.

FORGE WELDING

Forge welding of steel or iron requires that the parts be heated to a WHITE HEAT (about 2500°F.) and then hammered together. To avoid burning, the metal should be welded as soon as the proper temperature is reached. The metal won't weld when it cools, so make every hammer blow count.

The ends to be joined should be preshaped, by forging or cutting, to one of the shapes shown in figure 169. The beveled end is known as a SCARF. If the extra metal is not provided, the welded area will be thinner and weaker than the rest of the piece.

Borax and fine dry sand or a mixture of borax and sal ammoniac are used as fluxes for forge welding. The flux melts and flows over the metal to prevent oxidation of the

surface. It also acts to remove the oxides already formed on the metal due to heating.

Because of the development of gas and arc welding equipment and methods, and the availability of this equipment on ships and stations, you'll not do much forge welding. You should, however, know the principles and procedures—just in case.

MEASURING AND MARKING STOCK

Measure along the NEUTRAL AXIS (circular centerline) of a bar or rod to determine the finished length of bent or

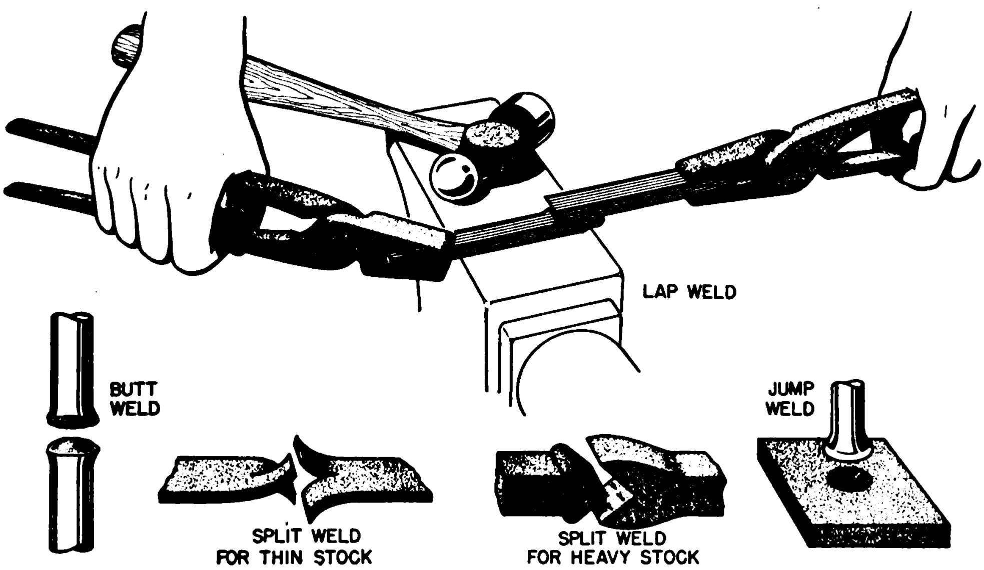

Figure 169.—Joints for forge welding.

formed pieces. Take the ring in figure 170 as an example—

The ring is made of 1 inch stock and must have a finished inside diameter of 6 inches. What length of stock is required?

The neutral axis diameter is 7 inches ($6'' + \frac{1}{2}'' + \frac{1}{2}''$).

The diameter of any circle multiplied by π gives you its circumference (distance around). So multiply 7 by π in order to get the length of stock needed—

$$7 \times 3\tfrac{1}{7} = 22$$

Add a small allowance—about $\frac{1}{8}$ inch in this case—for welding and you have $22\frac{1}{8}$ inches, the length of 1 inch stock needed for a circle having an inside diameter of 6 inches.

It's easy to tell what length stock is needed to make the angle shown in figure 170—simply 2 times 7½ or 15″. To determine the length of stock for the link, consider the two ends as forming a complete circle. The length of the neutral axis of this circle is $1\frac{1}{2} \times \pi$ or $4\frac{5}{7}''$—roughly $4\frac{3}{4}''$. Now add the length of the two straight sides (4″) and allow about ⅛″ for welding. Then $4\frac{3}{4} + 4 + \frac{1}{8} = 8\frac{7}{8}$. So you need a piece of stock 8⅞″ long to make this link.

Measurements on pieces of iron and steel are laid off with a steel rule or square and marked with a thin slab of soapstone. The soapstone mark will remain on the metal during heating.

When you measure and mark a piece of red-hot metal, you'll have to allow extra metal for the CONTRACTION

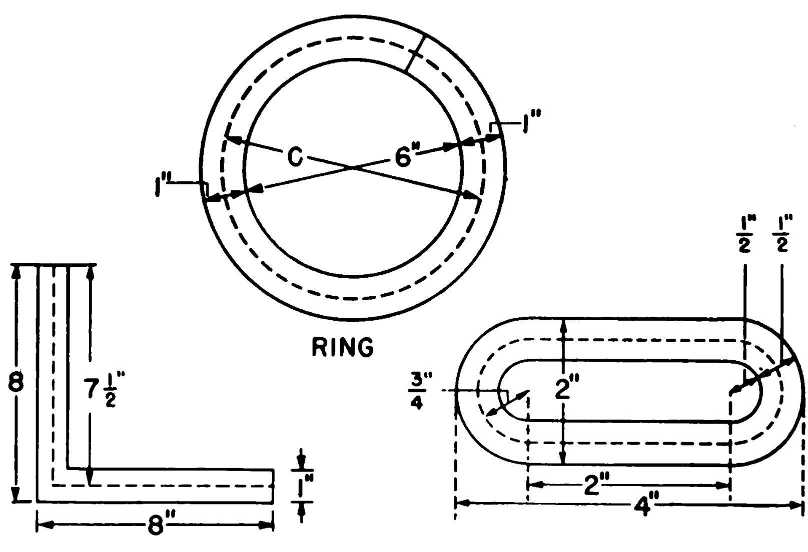

Figure 170.—Measuring stock for bending.

(shrinking) of the metal when it cools to room temperature. A steel rod 1 foot in length will contract about ⅛ inch when cooled from a full red heat.

FORGING A CHAIN LINK

To forge a chain link follow these steps as pictured in figure 171.

1. Bring the bar to the forging temperature and bend it to a U-shape over the anvil horn.
2. Scarf the ends (for forge welding only).

3. Curve the ends by shaping over the horn.
4. Bring the ends together and weld.

MAKING A CAPE CHISEL

The steps in forging a cape chisel are illustrated clearly in figure 172. When the forging is done, the tool must be heat-treated. Here's how you do it—

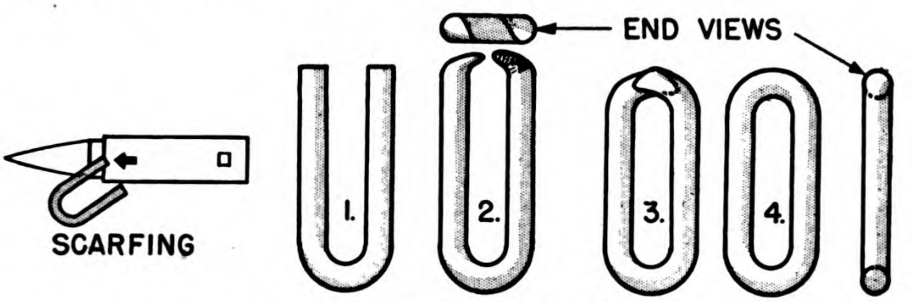

Figure 171.—Forging a chain link.

After the chisel is shaped by forging, HARDEN the point by reheating it to about 1450°F. and quenching it in water. Quench ONLY the point (about 1").

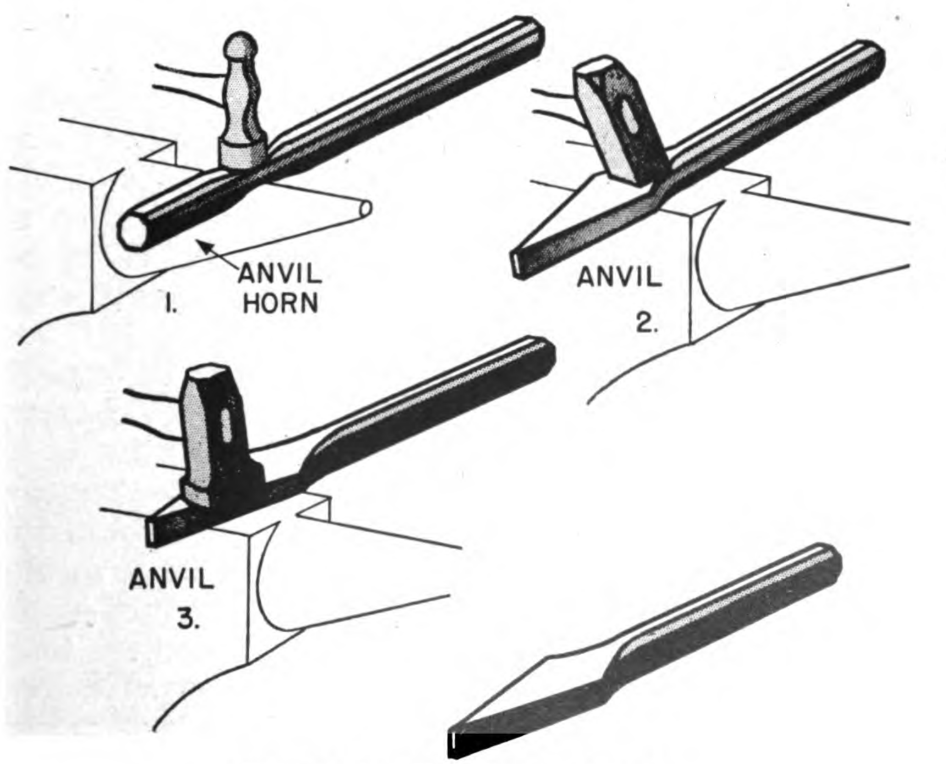

Figure 172.—Forging a cape chisel.

After the point has cooled, pull it out of the water and clean it with emery cloth.

The heat remaining in the chisel body will be conducted to the point and will heat the point enough for DRAWING. For a cape chisel, allow the oxides on the cleaned point to reach a DARK BLUE color, then quench the point in OIL.

The pounding end (head) of the chisel is then hardened by an oil quench at 1450°F. This end is then TOUGHENED by reheating it to a FAINT RED and allowing it to cool SLOWLY. Avoid reheating the point or you'll "draw" the temper.

The last step is to dress the point. Do this by touching it up on the grinder.

A chisel heat-treated in this manner will have a point which is extremely hard, without being brittle. The pounding head will be tough and shock-resistant.

CHAPTER 12

IRON AND STEEL

SHIPS OF STEEL

John Paul Jones won great naval victories with wooden ships. In fact, our Navy and the navies of the world were made up of wooden ships until the Merrimac—a wooden ship with an iron shell—steamed into action at the terrific speed of four knots and started sinking wooden ships left and right. She really went to town. It took another iron ship—the Monitor—to stop her. Those two ironclads of the 1860's were the granddaddies of the thousands of STEEL ships that make up our present fleet.

If all of these ships—and their engines, armor, and armament—were made of one kind of steel, the Metalsmith's work would be easier. But modern ships are made up of many kinds of iron and steel and other metals such as copper, brass, bronze, and lead.

This chapter is about the FERROUS metals (iron and steel). Chapter 14 is about the other metals—the NON-FERROUS ones.

FERROUS METALS

All metals containing a high percentage of IRON—those made from IRON ORE—are called FERROUS METALS. Why?

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Because the Romans worked with a metal they called FERRUM. This ferrum was the same as what we call iron.

The commonly used ferrous metals—cast iron, wrought iron, and the carbon steels—usually contain more than 90 percent iron. The other 10 percent or less is made up of such elements as silicon, sulfur, carbon, phosphorous, copper, aluminum, and tin. ALLOY STEELS—the cream of the crop—also contain high percentages of iron.

IRON ORE is the source of the PIG IRON from which the ferrous metals are made. Pig iron is made by refining the iron ore in a blast furnace and casting the refined metal in pig molds. Each pig (bar) weighs about 100 pounds. These pigs are remelted at the foundry or mill, and the other elements are removed, added, and controlled during the melting process to produce the desired types of metals.

PROPERTIES OF METALS

One reason metals are so valuable is that they can be selected and manufactured to fit almost any requirement. Each metal or alloy (mixture of metals and other elements) has its own characteristics and properties. These characteristics and properties are determined by three things—

Composition of the metal.
Method of manufacture.
Heat-treatment and cold-working.

As a Metalsmith you are directly concerned with heat-treatment and cold-working—you can't do anything about the first two items. Cold-working means bending, rolling, twisting, and pounding the metal without heating it. This mechanical working of metal results in changes in its properties and characteristics. Heat-treatment also changes the characteristics and properties of metal—so much that all of Chapter 13 is concerned with heat-treatment.

You need to know about the properties of the various metals so you can select and use them intelligently.

The properties of a metal are determined and judged by the way the metal behaves when it's subjected to STRESS caused by external (outside) forces. Take a look at figure 173. The PUSHING stress is called COMPRESSION.

The PULLING stress is known as TENSION. A BENDING stress produces a combination of compression and tension. When a metal is TWISTED the stress is called TORSION. SHEAR is a slicing or sliding stress.

The result of the stress upon a metal is called a STRAIN. Strain shows up as a change in the dimensions of the metal—it becomes wider or narrower, longer or shorter, thinner or thicker. If the metal does not return to the old dimensions after the stress has been removed, the ELASTIC LIMIT of the metal has been exceeded. If the metal returns to its original size after the strain is removed, the strain was within the elastic limits. The elastic limit, then, is a measure of the ELASTICITY of the metal. This elasticity is an important consideration when you are selecting metal stock for making or repairing metal parts or structures.

The ELASTICITY of a metal is determined by the extent to which it can be deformed (mashed, stretched, or twisted) without rupture—cracking and breaking.

The YIELD POINT of a metal is the point at which the metal BEGINS to give way under stress. The yield point is

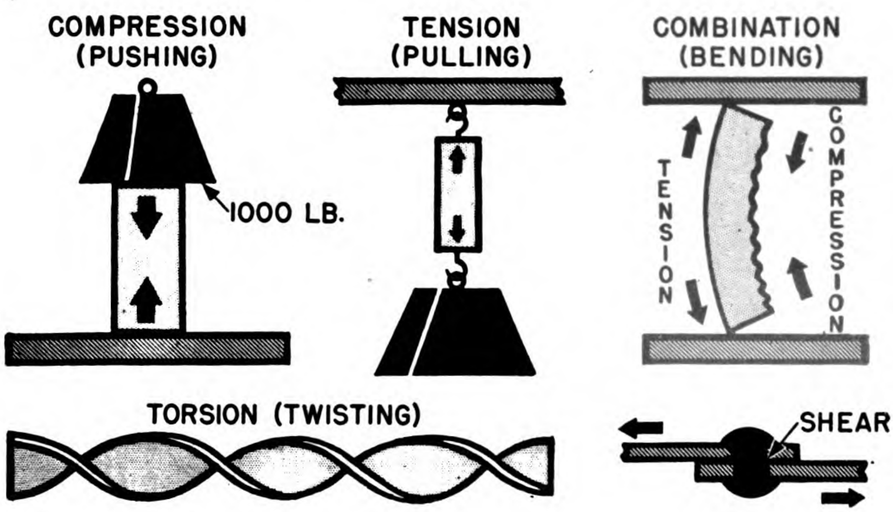


Figure 173.—Kinds of stress.

reached at a greater stress intensity or LOAD than that required to reach the elastic limit. When the stress (load) is increased ABOVE the yield point, the metal ruptures—breaks. The stress at which this failure occurs determines the ULTIMATE STRENGTH of the metal.

The ultimate strength of a metal under PRESSURE stress

is known as its COMPRESSIVE STRENGTH; under tension (pulling) stress it's called TENSILE STRENGTH. These strengths are stated in terms of POUNDS of force per SQUARE INCH—usually abbreviated to psi.

Engine and machine parts and structures are normally designed to withstand about four times the stress to which they are to be subjected. This is called the SAFETY FACTOR. It is usually 4 to 1 but may be as high as 20 to 1.

FATIGUE FAILURE is caused by repeated loading or stressing of the metal, especially when the stress is applied in different ways and from different directions. Vibration is one important cause of fatigue failure. Automobile axles and ship propeller shafts sometimes break because of fatigue failure.

HARDNESS is a property of metal that is determined by its ability to resist cutting, abrasion, or denting. Such parts as high-pressure steam valve knife-edges must be extremely hard. Metals that are extra hard are usually BRITTLE—they lack elasticity and plasticity.

TOUGH metals are hard, elastic, and durable. Steel must have this property when it's used to make cams, gears, levers, shafts, and tools. The quality of toughness is given to the hard steels by a hardening and tempering process. Tough metals resist shock and will bend, compress, or stretch considerably before they will break. Brittle metals break easily under the shock of being struck with a hammer.

DUCTILITY is the property of metal which allows it to be stretched or drawn out. Ordinary soft steel wire has a high degree of ductility.

MALLEABILITY is that property which allows metal to be hammered, rolled, bent, and twisted without causing cracks or breaks. One measure of the malleability of a metal is the thinness of the sheets into which it can be rolled. Ductility and malleability are related properties—both are the opposite of brittleness.

THERMAL CONDUCTIVITY refers to the HEAT conduction (carrying) characteristics of a substance. ELECTRICAL CONDUCTIVITY and thermal conductivity of metals are closely related—a good heat conductor is usually a good "juice" conductor.

Steel alloys are classified as ferrous metals because they are largely composed of iron. They contain carbon

but their characteristics and properties are further influenced and determined by the addition of other elements such as tungsten, molybdenum, chromium, nickel, and copper.

Now you will be able to understand these terms as they are applied to specific metals.

INGOT IRON

Ingot iron is almost pure iron—it's 99.9 percent pure. Perhaps you have heard it called "black iron." This iron is highly ductile and malleable because it contains such a small amount of carbon. Because of its purity, it is more resistant to rust corrosion than most ferrous metals. It holds paint and enamel well without special treatment or undercoats. Its chief disadvantage is that it lacks strength. Because of this drawback, ingot iron is used only where strength is not an important factor.

BLACK IRON SHEETS are easily formed to make such things as hoods, cabinets, cover plates, baking pans, guards and stove pipes. The ingot iron is soft enough so that it's easily drilled and riveted. It's also readily welded and brazed.

Sheets of black iron are usually furnished in the standard size—3 feet wide and 8 feet long. Sheet thickness is designated by the U.S. Standard gage numbers, which

THICKNESS OF IRON AND STEEL SHEETS

Gage	Thickness	Gage	Thickness	Gage	Thickness	Gage	Thickness
10	.1406	16	.0625	22	.0312	28	.0156
11	.1250	17	.0562	23	.0281	29	.0140
12	.1093	18	.0500	24	.0250	30	.0125
13	.0937	19	.0437	25	.0218	31	.0109
14	.0781	20	.0375	26	.0187	32	.0101
15	.0703	21	.0343	27	.0171		

Figure 174.—Standard gages of iron and steel sheets.

range from 38 (0.006″) to 0000000 (½″)—the bigger the number the thinner the sheet. The thickness of black iron PLATES is measured in inches and parts of inches or by the weight in pounds of metal per square foot of surface.

Figure 174 is a table of the standard gages from 10 to 32. These gages are the ones that you will use most frequently.

GALVANIZED IRON (G.I.) sheets are made from BASE PLATES (or sheets) of ingot iron which are coated with zinc. The base plates or sheets are thoroughly cleaned and then dipped into vats of molten zinc. The sheets are pulled out as soon as they reach the temperature of the molten zinc. These zinc-coated sheets have a bright, spangled appearance and are corrosion-resistant.

Because zinc coating will gradually deteriorate through oxidation, galvanized sheets are often painted. A special zinc coating called PAINT GRIP has been developed because ordinary zinc coatings do not paint well.

Galvanized sheet thickness is measured with a U. S. Standard gage. The sheets will be about one gage thicker than black iron sheets because of the coating.

You'll have to be careful when you bend and form galvanized metal or the zinc coating will flake and scale away from the base metal. Avoid sharp bends and hammer blows. If pounding is necessary, use a wooden mallet or a soft-faced hammer. The less pounding you do, the less trouble you'll have with the zinc coating.

Small parts and fittings, containers, and pipes, are often dip-galvanized after they are formed or shaped. Galvanizing can be done by methods other than dipping but the dipping method is considered to be the best.

TIN PLATE is made in the same way as galvanized iron except that the coating material is pure tin. Tin plate is made only in thin sheets. It's obtainable in "base boxes" of 112 sheets, each 14 inches x 20 inches. Larger sheets (20″ × 28″) are packed 112 to a "case" or "double-box." The heaviest sheets are packed 56 to the box.

Tin plate is ordered by the weight per "base box"—weights range from 100 to 215 pounds. COKE TIN PLATE is specified as "Cokes" (light coating), "Best Cokes" (medium coat), and "Kanner's Special" (heavy coating). CHARCOAL TIN PLATE is ordered by base weight and by coating symbols A, 2A, 3A, etc.

Galley utensils are often tin-plated because the tin is non-corrosive and does not contaminate food. Tinned articles are not used for high temperature heating because the tin has a low melting point.

WROUGHT IRON

Wrought iron is made by removing most of the other elements from pig iron by a process known as PUDDLING. Because puddling is such a slow procedure, a new method —known as the DUPLEX process—is now used for making large quantities of wrought iron.

During the manufacturing process, from 1 to 3 percent of fibrous slag is mixed with the metal. This slag and the purity of the iron help prevent corrosion. Aboard ship wrought iron is used for piping. Not long ago it was about the only metal used for corrosive salt water lines.

Because it is easily forged and welded, wrought iron is often used to make small fittings and brackets. This iron has great resistance to shock but it cannot be hardened by heat treatment. Protective coatings—paint and enamel —hold well on wrought iron. It is easily galvanized. The tensile strength of wrought iron is about 40,000 to 55,000 psi.

CAST IRON

Cast iron is made by remelting and refining pig iron in a furnace—usually a cupola furnace. The metal is heated to the required temperature and poured into sand molds to form castings.

They CANNOT be bent, twisted, or rolled. Cast iron castings CAN be worked by chipping, filing, machining, and grinding. Cast iron is extensively used for machine bases and machine and engine parts that require weight and rigidity but do not require great strength or shock resistance.

GRAY CAST IRON—the kind used most—is a mixture of many ferrous and non-ferrous elements. The content of these elements is determined by their presence in the ore and in the coke used as fuel for the cupola. The content of such elements as carbon, silicon and sulfur, may be controlled and varied through furnace control during the melting process.

The following table shows the content of six important elements present in gray cast iron—

Small amounts of nickel, chromium, and molybdenum are sometimes added to cast iron to increase its strength and to make it more resistant to heat and acid corrsion.

Gray cast iron has a dull, dark gray color. It machines readily to a smooth finish and does not chip easily. It becomes dull red just before it melts. In the molten condi-

Iron—94 to 97%	Sulfur—less than .2%
Carbon—2 to 4%	Phosphorus—less than .75%
Silicon—1% or more	Manganese—less than 1%

tion it is fluid and watery. When melted the gray iron has a reddish white color. Its tensile strength is from 20,000 to 40,000 psi.

HIGH STRENGTH GRAY CAST IRON has a tensile strength exceeding 40,000 psi. This extra strength is obtained by superheating the molten iron to a temperature of 2,800°F. before the molds are poured.

WHITE CAST IRON is extremely brittle and does not machine readily. Because it's tough stuff to work with, it is not used much in the "as is" condition. Its principle use is for making MALLEABLE CAST IRON. Malleable cast iron castings are the result of annealing white cast iron castings in a furnace for several days. The annealing (softening) process increases the shock resisting quality of the iron and raises the tensile strength to about 60,000 psi. Malleable cast iron is hard to chip, and its chips are much larger than those of gray cast iron.

SPARK TEST FOR IRON

Ferrous metals may be identified by touching a sample piece to a revolving grinder wheel. The metal is identified by the length, spread, volume, and color of the shower of sparks and by the shape of the individual sparklers. The sparks for gray cast iron and wrought iron are diagramed in figure 175.

THE MASTER METAL—STEEL

Navy ships and most of the Navy small craft are made of STEEL because steel is strong, tough, and durable. Keels, decks, bulkheads, ladders, ground tackle, engines—are all made of steel. Armor and armament are made of steel as are the projectiles that destroy the enemies' fleets. And most of your tools are made of steel—your snips, shears, hammers, stakes, and a long list of others.

It's obvious that just one kind of steel isn't suitable for all these jobs. Therefore, steels are developed, selected, and used to FIT THE JOB. It's up to you to know about steel so you can select the right kind and use it properly.

There are two important classifications of steel—CARBON STEELS and ALLOY STEELS. Alloy steels contain carbon too, but they also contain controlled amounts of other elements. Nickel, chromium, tungsten, molybdenum, and manganese are some of the elements added to carbon steel to produce alloy steels. As alloy steels are the best of the steel family, they are used for armor plate, guns, special

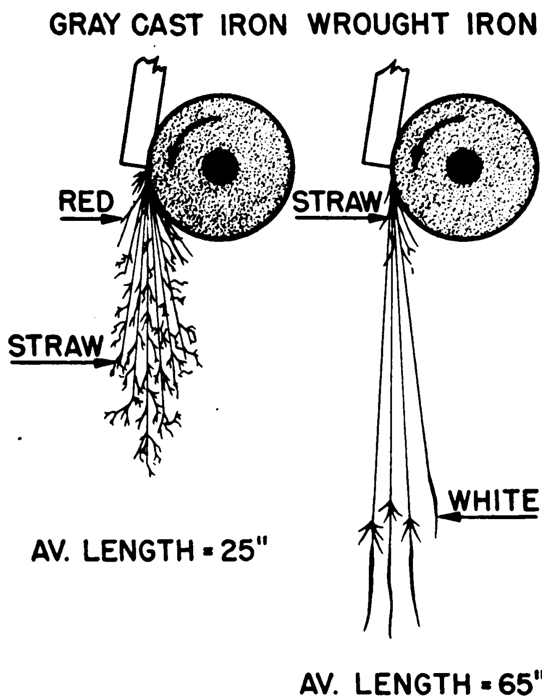


Figure 175.—Spark-testing iron.

tools and any other purpose where extra strength, long wear and corrosion-resistance are required. Because they are expensive, alloy steels are seldom used for general construction.

Carbon steel is really an alloy of iron and carbon but it is seldom referred to as an alloy. The properties and characteristics of the various kinds of carbon steel are largely dependent on the AMOUNT OF CARBON in the steel.

CARBON CONTENT

How does carbon steel differ from iron? The difference is largely a matter of CARBON CONTENT. Soft ingot iron

and wrought iron usually contain less than one-tenth of one percent (0.10%) carbon. Cast iron generally contains from two to four percent (2-4%) carbon. The carbon content of steel falls in the range between that of the soft irons and the cast irons—it's usually from one-tenth of one percent (0.10%) to one and two-tenths percent (1.2%) carbon. It may be as high as one and seven-tenths percent (1.7%) carbon.

The carbon content of steel is often expressed as "points of carbon" or just as "points." One point is equal to .01%. If a man says he is using 40 point steel you'll know that he means the steel contains 40/100 percent (0.40%) of carbon.

The HARDENING ABILITY of a steel is largely dependent on its carbon content. As a general rule, the MORE CARBON

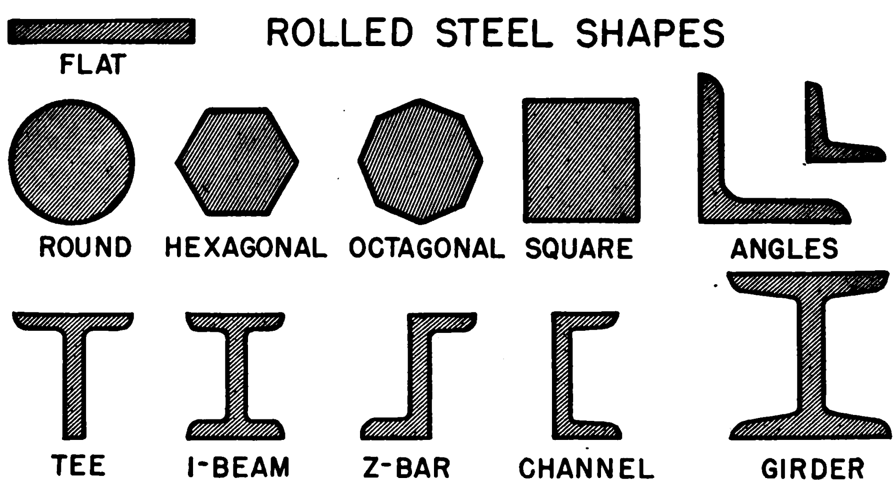


Figure 176.—Steel shapes.

a steel contains the GREATER will be its hardness and rigidity and the more brittle it will be.

The composition of the carbon steels is similar to that of iron—they are both made from the same iron ore or pig iron. It's the amount or PERCENTAGE OF CARBON THAT MAKES THE BIG DIFFERENCE IN PROPERTIES.

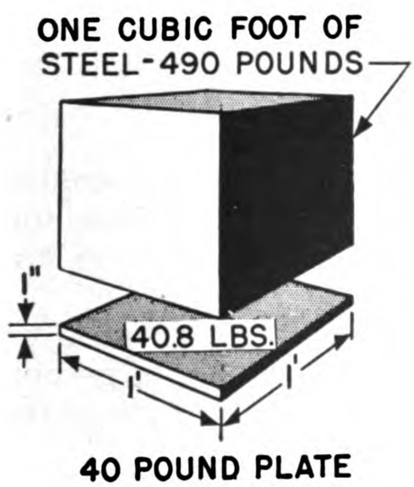
Carbon steels are sub-divided into LOW-, MEDIUM-, and HIGH-carbon steels, according to their carbon content.

LOW-CARBON STEEL

Common construction steel contains from 0.05% to 0.30% carbon and is called low-carbon steel or "mild steel." Mild steel is ductile and malleable and is READILY

rolled, formed, drawn, forged, machined, and welded. It cannot be hardened to any great extent by heat treatment. It may be surface-hardened (case-hardened or carburized) if the carbon content is less than 0.20%. The tensile strength of low-carbon steel ranges from 45,000 to 75,000 psi.

Low-carbon steel is available in the form of sheets, plates, rods, wires, bars, and structural shapes (figure 176). The steel is rolled and shaped while it is red hot. Cold-rolled and cold-drawn sheets, plates, and shapes are worked hot to oversize dimensions and then finished to size by cold working. The cold-worked steel is stronger than hot-worked steel but not so ductile. Hot-rolled sheets and plates have a hard, black scale; cold-rolled stock has a bright, clean, smooth surface.



STEEL PLATE

THICKNESS	NAME
2"	80 POUND
$1\frac{1}{2}$"	60 POUND
1"	40 POUND
$\frac{3}{4}$"	30 POUND
$\frac{1}{2}$"	20 POUND
$\frac{3}{8}$"	15 POUND
$\frac{1}{4}$"	10 POUND
$\frac{1}{8}$"	5 POUND
$\frac{1}{16}$"	$2\frac{1}{2}$ POUND
BELOW $\frac{1}{16}$"	SHEET

Figure 177.—Thickness and weight of steel plate.

Low-carbon steel is used for making frames, plates, pipes, tubes, and beams. It is also used for forgings if exceptional strength is required. Sheets and plates may be galvanized. These sheets and plates are available in the same sizes and gages as sheets of galvanized and black iron. Low-carbon steel is also used as the base metal for tin plate.

MEDIUM-CARBON STEEL

Medium-carbon steel has a carbon content of 0.30% to 0.60%. Its tensile strength ranges from 70,000 to 120,000

psi as rolled. This strength can be almost doubled by suitable heat treatment. Medium-carbon steel is made in much the same manner as low-carbon steel but is not so ductile when cold-worked.

Because of the extra strength of the medium steels, they are used for shafts, connecting rods, axles, and for forgings that require extra-strength.

Steel plates for ships' hulls are rolled from steel that has a carbon content of about 0.31 percent. The steel in these plates weighs about 490 pounds per cubic foot. A piece of plate that is one inch thick, one foot wide, and one foot long weighs about 40.8 pounds, so any steel plate that is one inch thick is called "forty-pound plate." Figure 177 gives a comparison of other sizes.

Gages of metal sheets range up to number 0000000 (½ inch) but anything over ⅛ inch is seldom gaged. If it's ⅛ inch or under it's commonly called SHEET; if more than ⅛ inch it's usually known as PLATE.

HIGH-CARBON STEEL

High-carbon steel—often called tool steel—contains more than 0.60% carbon. This steel is used to make tools, special springs and machine parts that must be hard, tough, and strong.

Carbon steel containing 0.60 to 0.65% carbon is used for hammers and dull-edged tools. Reamers, large drills, and dies are made of steel with 0.65 to 0.85% carbon. Steel containing 0.85 to 1.10% carbon is used to make chisels, knives, saws, drills, and lathe tools. Your pocket knife blades are made of this steel. Steel having more than 1.10% carbon is used to make tools for fine work—small drills, engraving tools, milling cutters, and razors.

The steel ordinarily used for the forging of tools contains from 0.60 to 0.90 percent carbon. Various degrees of hardness and softness are obtained by heat treatment—hardening and tempering.

IDENTIFICATION OF CARBON STEELS

Here are four simple tests you can apply to determine the approximate carbon content of a piece of steel—

FILE IT. You'll soon learn to tell the comparatively soft low-carbon steels from those with higher carbon content. The lower the carbon content, the more easily

the file will cut. If the file won't cut at all, the steel contains approximately 1% carbon or more—it's as hard as the file.

BEND IT. The more easily the steel bends, the lower the carbon content. If it won't bent easily, the carbon content is high.

DENT IT. Use a punch or cold chisel to make an indentation test. If the steel dents easily, it's low-carbon. If the punch or chisel won't dent it, or only dents it slightly, the steel has a high carbon content.

GRIND IT. The sparks and sparklers made by grinding low-carbon, high-carbon, and one alloy steel (stainless steel) are shown in figure 178.

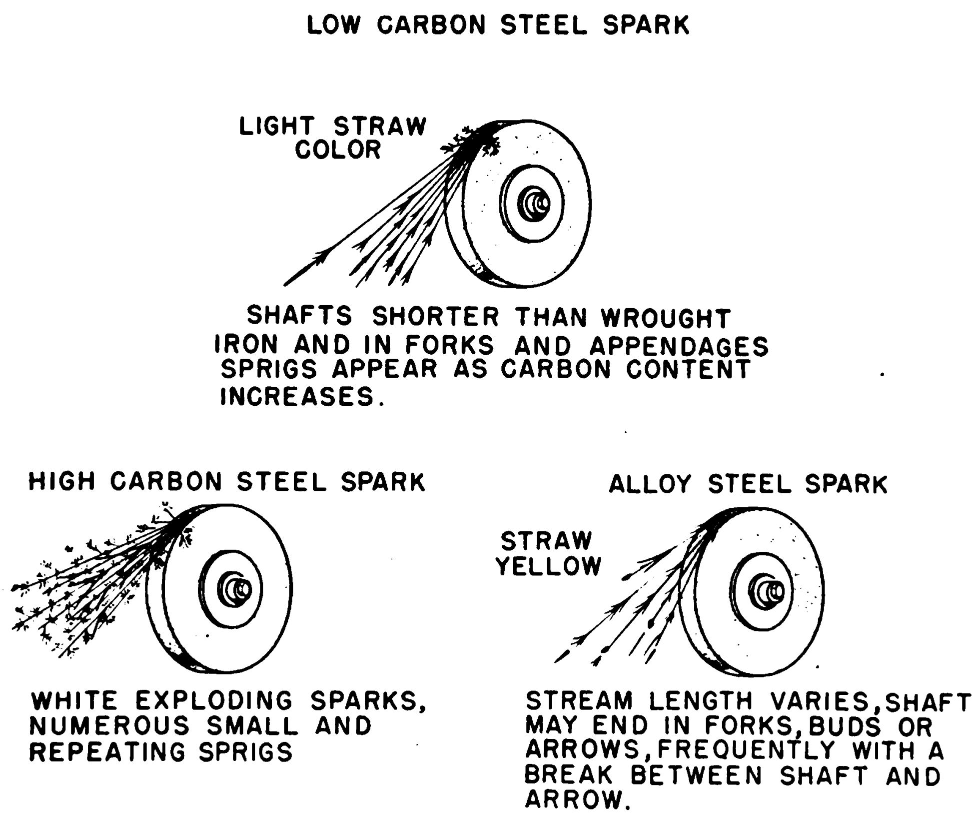


Figure 178.—Spark-testing steel.

ALLOY STEELS

While ordinary carbon steel is really an alloy (mixture) of iron and carbon, it is not commonly called an alloy unless other elements such as nickel, chromium, vanadium, and tungsten, are added during manufacture. One, two, or several ALLOYING AGENTS (elements) may be added to steel at the mill to secure the desired characteristics. The

characteristics or properties of a steel alloy are largely determined by the CONTENT of the alloying agents and by the HEAT TREATMENT to which the alloy is subjected.

NICKEL STEEL usually contains from 3% to 5% of nickel and from 0.15% to 0.45% of carbon. The addition of the nickel raises the elastic limit of the steel and increases its tensile strength. The nickel also increases the corrosion resistance of the steel. Because of their toughness, it's difficult to machine nickel steels.

CHROMIUM STEEL is used to make parts that must resist wear. The chromium content usually ranges from 0.5% to 1.5%. Ball bearings are usually made of a chromium steel containing about 1% chromium and 1% carbon.

CHROME-NICKEL STEELS are commonly referred to as "stainless steels." But because these alloys are not completely "stainless," the Navy calls them C.R.S. (Corrosion-resistant steels). Over 40 different alloys of this type are on the market. You'll probably use the one called "18-8" —so named because it contains approximately 18% chromium and 8% nickel. The carbon content of "18-8" ranges from 0.08 to 0.25%.

CHROME-VANADIUM steel is used to make tools and machine parts that require maximum strength and minimum weight. If you'll look at a set of good 12-point box-end wrenches, you'll see "chrome-vanadium" on the handles. Crankshafts, gears, and axles are made of this super-strong alloy. It contains 0.15 to 0.25% vanadium, 0.60 to 1.50% chromium, and 0.10 to 0.60% carbon. It may also contain some nickel.

In order to increase its hardness, tungsten is often alloyed with steel. HIGH-SPEED STEEL is a special tungsten steel alloy. A good grade of high-speed steel contains 13 to 19% tungsten, 1 to 2% vanadium, 3 to 5% chromium, and 0.60 to 0.80% carbon. This alloy is one of the most expensive to produce and its use is mostly restricted to the manufacture of cutting tools such as drills, lathe tools, and milling cutters. The tungsten imparts the remarkable quality of "red-hardness" to the steel. Tungsten steel tools keep right on cutting even when they become red hot.

MOLYBDENUM is often used as an alloying agent for steel in combination with chromium and nickel. The "moly" adds toughness to the steel. It's used instead of tungsten to make cheaper grades of high-speed steel.

NATIONAL EMERGENCY STEELS were developed during the early part of World War II because of the scarcity of some of the alloying elements—tungsten and vanadium in particular. As these alloy steels have proven satisfactory, many of them are used interchangeably with the older and more expensive standard alloys.

STEEL CASTINGS

Steel castings are used where cast iron would not provide the necessary strength and toughness. Almost any kind of steel can be cast in sand or steel molds. Properties of cast steel are determined by the content of the steel, the method of heating and casting, and the heat treatment.

Castings that must be machined to size and fit are usually made of a low-carbon steel or an alloy that cuts freely and machines to a smooth finish. Tough, hard castings are generally ground to size.

WARNING

If you WELD or otherwise HEAT castings of any kind, be sure that there are no enclosed AIR POCKETS or spaces. Terrific explosions may occur when enclosed pockets or cores containing gases or liquids are heated to high temperatures. The trapped gases or liquids exert almost unbelievable pressure as they are expanded by the heat. This pressure often is great enough to tear the casting apart and send pieces flying through the air.

Before you work on a casting having an enclosed space be sure the space is VENTED. Some castings have removable CORE PLUGS. Others may be vented by drilling small holes to the enclosed spaces.

S.A.E. AND A.I.S.I. CLASSIFICATION

Standards have been established for the classification of carbon and alloy steels. The many different kinds of steel are classified according to element content by NUMBER SYMBOLS. Two accepted classification systems are the S.A.E. (Society of Automotive Engineers) and the A.I.S.I. (American Iron and Steel Institute).

Your shop library or ships' library probably contains pamphlets that list S.A.E. and A.I.S.I. steel and their properties.

The S.A.E. system uses a simple four-digit number symbol which indicates these three things—

General classification of the steel is indicated by the first digit.

Content of the principal alloying agent is indicated by the second digit.

Carbon content is indicated by the last two digits.

The general classification of the steel is indicated by numbers 1 through 9. Here's what each of the numbers means—

SYMBOLS	S.A.E. STEELS	SYMBOLS	S.A.E. STEELS
1xxx	Carbon	6xxx	Chromium-Vanadium
2xxx	Nickel	7xxx	Tungsten
3xxx	Nickel-Chromium	8xxx	National Emergency
4xxx	Molybdenum	9xxx	Silicon-Manganese
5xxx	Chromium		

Two samples of S.A.E. steels are explained below—

S.A.E. 1040	S.A.E. 3135
0.40% carbon	0.35% carbon
No alloying agent	About 1% nickel
Carbon steel	Nickel-chromium steel

You'll find a few exceptions to the above system—some symbols will contain FIVE digits. In that case, just use a little common sense to figure out the meaning. Here is a typical example of a five-digit symbol—

S.A.E. 71360
0.60% carbon
13% tungsten
Tungsten alloy

The A.I.S.I. classification system works on the same principle as the S.A.E. system. However, the A.I.S.I. symbols tell more about the steel. Here's how it is done—

A capital letter is placed in front of the number symbol to indicate the method used to manufacture the steel. For example, the letter *A* indicates an alloy steel made by the basic open hearth method, and the letter *B* indicates a carbon steel made by the acid bessemer process.

Each A.I.S.I. symbol represents a more limited classification than does each S.A.E. symbol. For example, S.A.E. 1040 includes all steels classified by A.I.S.I. as A1035, A1038, A1040, A1042, and A1043.

The Navy has set up its own symbols for identifying steel. These follow the standard Navy system for specification of materials and replacement parts. For example, a certain molybdenum alloy steel used for high-pressure piping is indicated by the symbol "44T33."

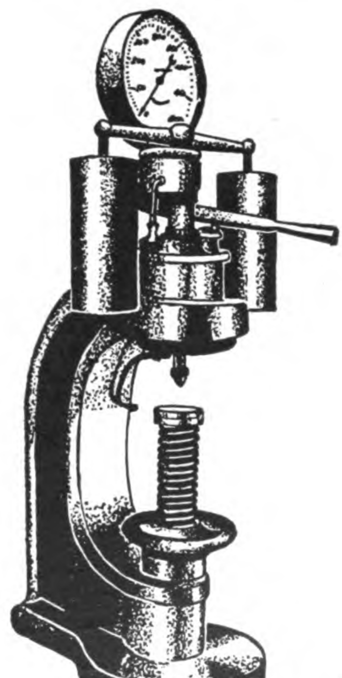


Figure 179.—Brinell hardness tester.

SCIENTIFIC TESTING OF METALS

Steel mills and foundries have special testing machines for checking tensile strength, yield point, ultimate

strength, hardness, and machinability. Accurate method and equipment are used to determine carbon and alloy content.

You will seldom get a chance to see, much less use, most of this equipment. But you may be required to use some type of HARDNESS-TESTING equipment. To pass advancement tests you must be familiar with the hardness-testing equipment available on your ship.

Your shop may have a Brinell Hardness Tester like the one shown in figure 179. This machine presses a hard steel ball into the object being tested. The dial hand (see

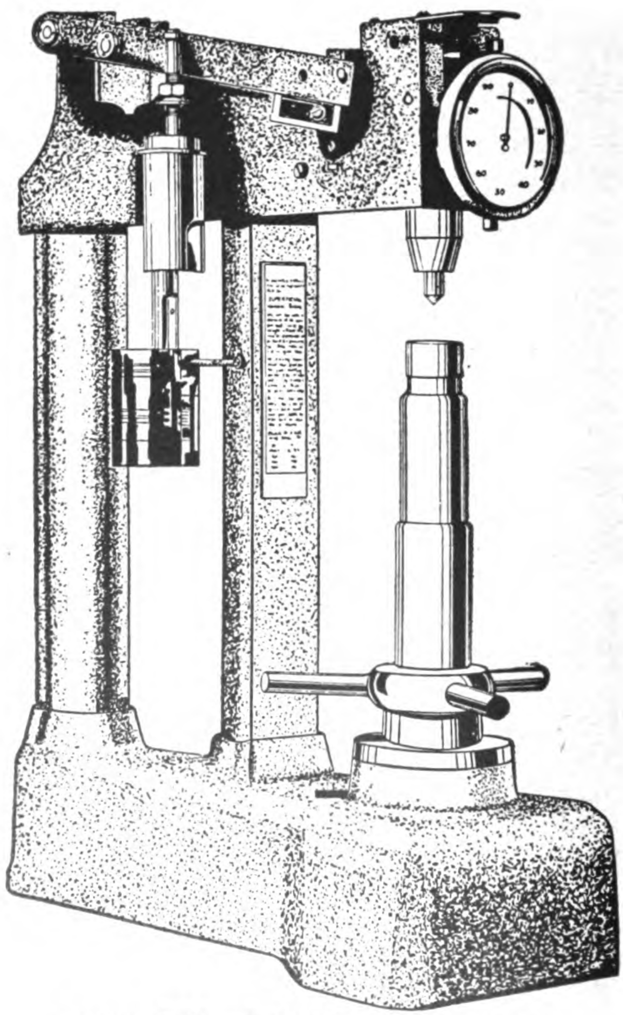


Figure 180.—Rockwell hardness tester.

figure 179) does not indicate the hardness but only the PRESSURE applied to the steel ball. The BRINELL HARDNESS NUMBER is obtained by a calculation involving either the

surface area of the impression made by the ball or the diameter of the impression.

The SHORE SCLEROSCOPE (figure 181) measures hardness by the height of the "bounce" of a small diamond-tipped hammer dropped on the piece being tested. The HARDER the material the HIGHER the bounce.

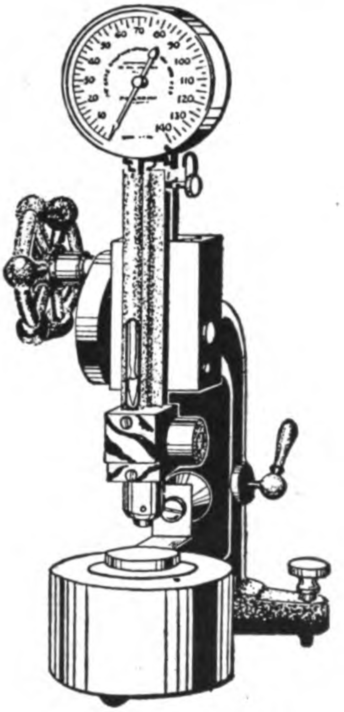


Figure 181.—Shore scleroscope.

The important thing about using any testing machine is to FOLLOW EXACTLY the manufacturer's directions that accompany the machine.

Hard metals will have small impressions and large numbers. Hardened steel containing 0.90% carbon has a Brinell hardness number of about 600. When annealed the same steel has a Brinell hardness of about 200.

The ROCKWELL HARDNESS TESTER (figure 180) measures the DEPTH of the impression made by a diamond cone (for hard metals)and a 1/16 inch hard steel ball (for soft metals). There are two hardness scales on the machine from which readings are taken—the B-scale for use with the steel ball and the C-scale for use with the diamond point.

CHAPTER 13

HEAT TREATMENT OF STEEL

WHAT IS HEAT TREATMENT?

You already know the purpose of heat treatment—to change the properties of a metal to fit the requirements of the job. But what is heat treatment? Here's a definition that covers all types and kinds—

> Heat treatment consists of heating and cooling metals, UNDER CONTROLLED CONDITIONS, to produce desired properties such as strength, hardness, toughness, softness, ductility, elasticity, and malleability.

The words—UNDER CONTROLLED CONDITIONS—are the key words of the definition. They apply directly to you because YOU will control the conditions of TIME and TEMPERATURE for heating and cooling metals undergoing heat treatment.

Heat treatment usually involves these three steps—

HEATING the metal to the proper temperature at the proper rate of heating.

SOAKING or HOLDING the metal at the proper temperature to insure uniform heating.

COOLING the metal to room temperature, either slowly or rapidly, as determined by the kind of heat treatment you're doing.

It's your CONTROL of time and temperature during these steps that determines the properties obtained by heat-treating. You can readily see that no ONE method of heat treatment can be used to take care of all jobs. Here are five kinds of heat treatment that you should know about—

ANNEALING—a softening heat-treatment process applied to metal pieces to permit forming, reduce brittleness, improve machinability, increase shock resistance, and remove gases from cast metal.

NORMALIZING—a process closely related to annealing. It's used to remove strains set up in metal parts as a result of cold-working, forging, casting, welding and hardening.

HARDENING—a process that makes most kinds of steel hard and brittle. Steel is ALWAYS annealed before it is hardened.

TEMPERING—a process that decreases the hardness and brittleness of a metal that has been annealed and then hardened. Some of the hardness is sacrificed to obtain strength and toughness. "DRAWING" and "TOUGHENING" are two methods of tempering.

CASE HARDENING—any process which increases the hardness of low-carbon steel parts by increasing the carbon content of the metal surface. The hardened shell may be only a few thousands of an inch thick or it may have a depth of more than one-eighth inch.

WHAT HAPPENS?

What happens to steel during a heat-treatment process to cause changes in its properties? The steel always looks about the same to the naked eye but certain CHANGES occur during heat treatment which transform the internal STRUCTURE of the steel. These changes in the structure of the steel are due to the effect of heating and cooling the IRON and CARBON of which the steel is composed.

Until the last few decades, little was known about what happened to steel during heat-treatment. Some heat treatment was done but it was by rule of thumb, and by hit-or-miss methods based only on experience and guesswork. In recent years scientific men known as METALLURGISTS have studied steel with microscopes, X-rays, and other equipment, and have discovered some of the things that happen to steel when it is heat-treated.

They have found that the crystalline structure of steel CHANGES during heating and cooling at CRITICAL POINTS established by breaks in the heating and cooling rates. (These critical points are slightly different for heating and cooling but you need not be concerned for most heat treatment jobs.)

CRITICAL RANGE is a term applied to the temperature interval between the two important critical points of a steel.

STRUCTURES OF STEEL

The crystalline structure of steel depends on the CHEMICAL CONDITION of the elements—iron and carbon—of which the steel is composed. The chemical condition is modified and changed when the steel is heated or cooled past the critical points or limits.

Take a look at figure 182. It diagrams the chemical changes which take place during SLOW HEATING to change the structure of any carbon steel with a carbon content of less than 83 points (0.83%). Notice the three structures —FERRITE, PEARLITE, and AUSTENITE. Ferrite and pearlite are both present below 1333°. Austenite and ferrite are both present through the critical range. Only austenite is present above the upper critical limit.

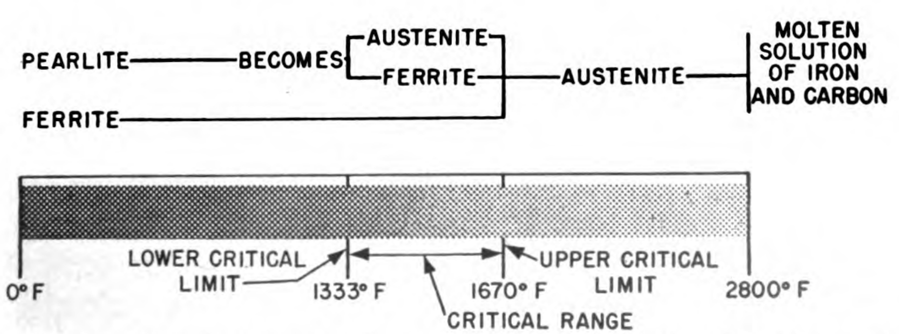


Figure 182.—Chemical changes in steel containing less than 83 points carbon, as affected by slow heating.

Remember—the diagram in figure 182 applies ONLY to steel with LESS than 83 points of carbon. These same changes are shown graphically in the left part of figure 183. Steels containing more than 83 points of carbon are shown at the right of this same figure.

Note that there is no ferrite in steel which contains more than 83 points of carbon. Instead there is another

structure called CEMENTITE. The presence of the cementite indicates a hard, brittle steel.

These structures—ferrite, pearlite, austenite, and cementite—can be seen only under a microscope. By following charts and specifications, Metalsmiths may get good results in heat treating without knowing anything about

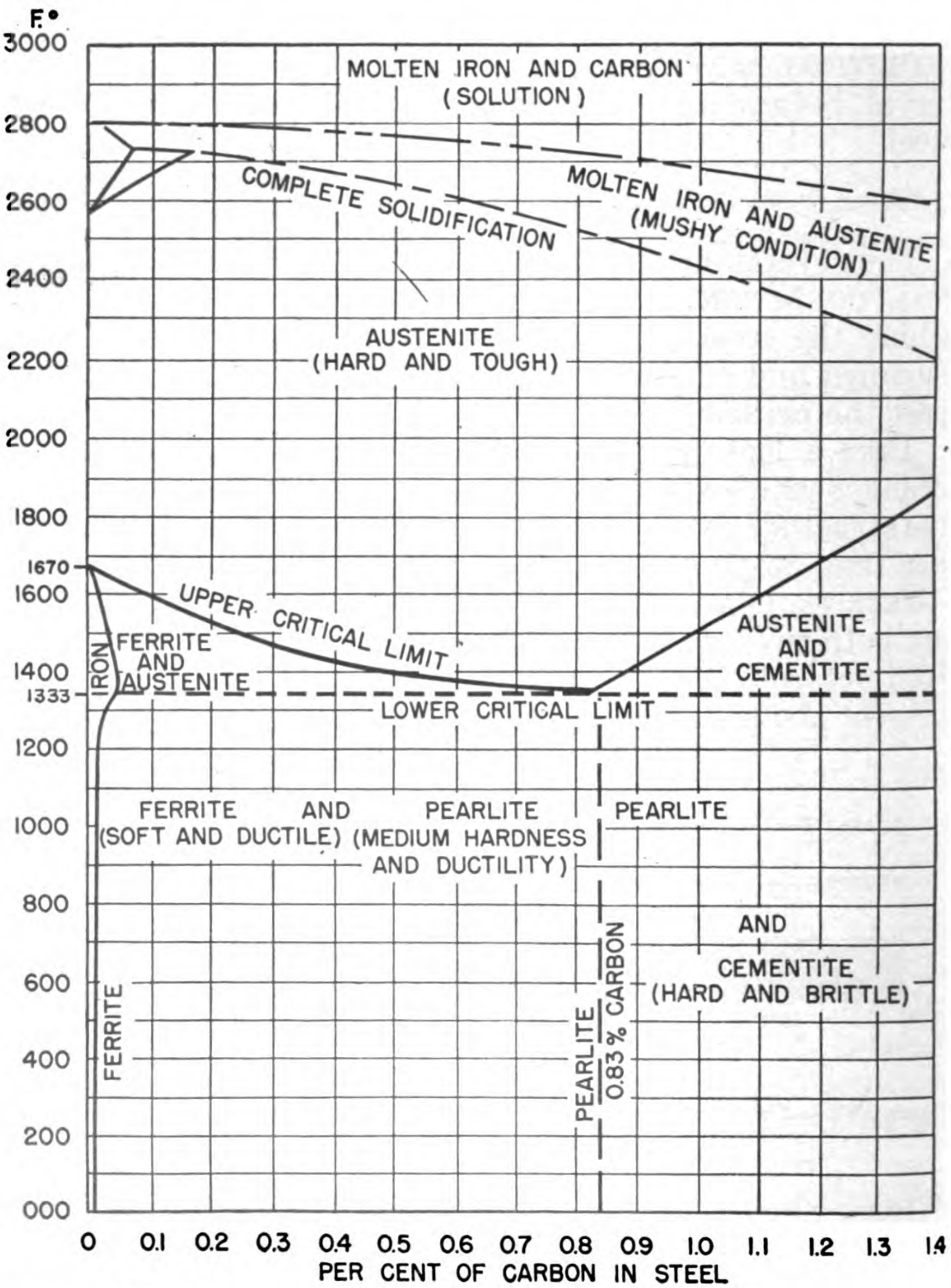


Figure 183.—Structure of steel; critical temperature points and limits when steel is slowly heated and cooled.

the chemistry of steel. But if you understand what happens to the steel during heat treatment, you can analyze mistakes and improve your work.

If you are interested in the chemistry of steel, contact your leading chief or your division officer. They may have some good books about the metallurgy of steel and other metals. Keep yourself well informed about steel and you won't have to scratch your head when someone uses such words as critical range austenitic steel, pearlitic steel and other technical terms.

PRACTICAL HEAT TREATING

For practical heat treatment of steel you need to be concerned most with CRITICAL POINTS or limits. You must know the carbon content BEFORE you can determine the upper critical point. This point is fixed by the carbon content.

You also must follow closely the directions for heating, soaking, and cooling for EACH KIND of heat treatment.

You can use the diagram in figure 183 as a guide for annealing, hardening, and normalizing. A tempering guide is shown in figure 186.

ANNEALING STEEL

Steel is easily softened by the full annealing process. All you have to know—or find out—about the steel is WHAT KIND it is. For carbon steels, this is determined by carbon content. For heat-treating alloy steels, you can refer to a TIME AND TEMPERATURE CHART to find the necessary information. Annealing temperature ranges for steel are diagramed in figure 184.

Here's the correct procedure for fully annealing steel—

Heat the steel slowly until the temperature is from 50° to 100° above the critical range. (See chart, figure 185.) Heating time depends on size and thickness. The temperature should be below 1100° F. when the steel is placed in the furnace.

Hold the annealing heat (soak) the steel long enough for the structure to change. About one hour is required for each inch of sectional thickness. Small tools require about one-half hour of soaking.

Cool the steel SLOWLY, either in the furnace or packed

in dry asbestos, ashes, or slacked lime. Large pieces require several days of cooling; small pieces need only a few hours.

PRECAUTIONS FOR ANNEALING

Do not overheat the metal. Excessive temperatures will increase the grain size and may even "burn" the steel. This burning removes the carbon. Avoid soaking for longer periods than are necessary. If steel parts are to be

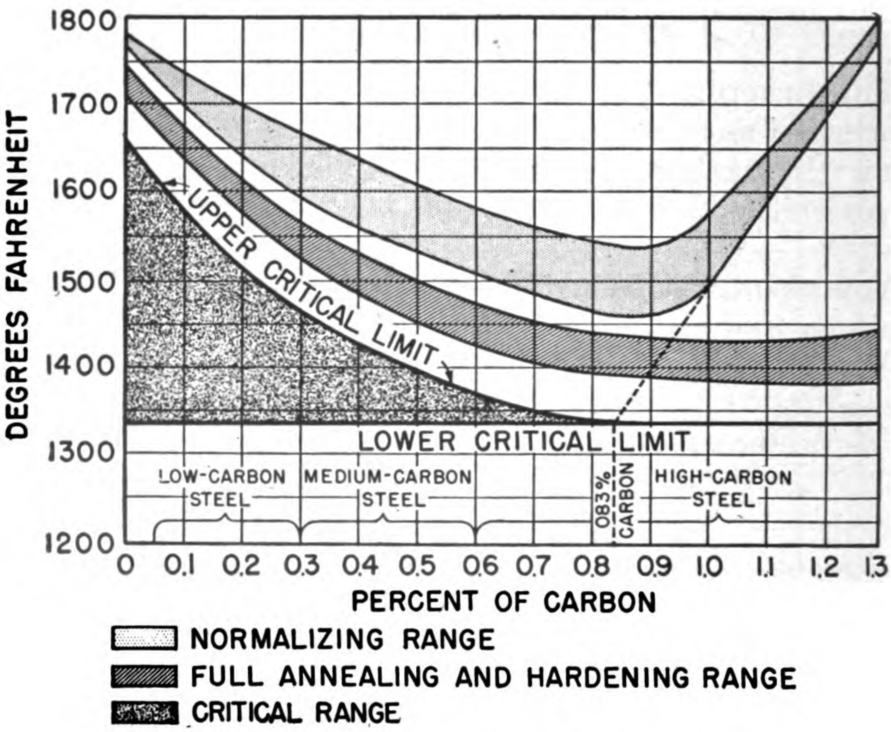


Figure 184.—Temperature ranges.

removed from the furnace for packing, have all equipment ready. Lose no time in making the transfer. Never allow air drafts to strike hot metal at any time because these drafts cause uneven cooling and set up strains in the metal.

NORMALIZING STEEL

The process of normalizing is used to relieve internal strains caused by cold-working, previous heat treatment, and welding. Normalizing softens steel slightly but does not reduce its strength or hardness to any great extent.

Normalizing is done by heating the steel to the proper temperature (see figure 184) and then cooling it in STILL AIR. Avoid overheating and extended soaking periods.

HARDENING STEEL

The first two steps in hardening steel are exactly the same as those for annealing—(1) SLOW HEATING to 50°-100° above the critical range, and (2) SOAKING until a uniform heat is obtained. It's the third step—COOLING—that makes the big difference. FAST COOLING is necessary for hardening; slow cooling is essential for annealing.

Fast cooling is accomplished by QUENCHING—dipping the hot metal in a liquid. Low-carbon and medium-carbon steels are usually quenched in water. To avoid excessive internal strains in the hardened metal, high-carbon and alloy steels are normally quenched in oil.

Some of the liquids commonly used for quenching are listed here, along with their comparative cooling rates. The value 1.00 represents the most rapid cooling action.

QUENCHING LIQUID	COOLING RATE
Brine (water with 10% salt)	1.00
Water (at 70° F.)	.76
Cottonseed oil	.27
Neats foot oil	.25
Fish oil	.23
Paraffin oil	.20
Machine oil	.17

Oils may be used for quenching alloy steels because the crystalline structure changes more slowly in these steels than in plain carbon steel. One of the main reasons for alloying steels is to CONTROL THE STRUCTURE CHANGES when the steel is quenched. The addition of the alloying elements actually slows up the chemical change of the structure so that most of the structure present at the quenching temperature is maintained in the treated metal.

Quenching baths are held in large tanks near the furnace. The hot steel must be quenched IMMEDIATELY after it is removed from the furnace. A treated piece should be agitated in the liquid to equalize the cooling action. Don't just toss a piece in the tank and forget about it—UNIFORM COOLING IS ESSENTIAL.

Large pieces should be dipped so that the heaviest sections enter the quenching bath first. If treated parts are removed from the furnace with tongs, the tongs should be preheated to prevent partial cooling of the parts before they are quenched.

Quenching temperatures for some of the commonly used steels are listed in figure 185, along with their tensile

S.A.E. STEEL	QUENCH AT	TENSILE STRENGTH (PSI) (Tempered at 1000° F.)
QUENCHED IN WATER		
1030	1575° F.	98,000
1035	1525° F.	103,000
1040	1500° F.	110,000
1045	1500° F.	120,000
QUENCHED IN OIL		
1060	1550° F.	122,000
1070	1525° F.	133,000
1080	1500° F.	143,000
1090	1450° F.	178,000
X1340	1500° F.	123,000
2330	1500° F.	125,000
2345	1475° F.	140,000
3130	1550° F.	130,000
X3140	1525° F.	150,000
3245	1500° F.	155,000
X4130	1550° F.	145,000
4140	1575° F.	156,000
X4340	1550° F.	187,000
4640	1500° F.	161,000
5150	1525° F.	167,000
52100	1550° F.	185,000
6150	1575° F.	179,000
9250	1650° F.	182,000
9260	1650° F.	188,000

Figure 185.—Quenching temperatures for hardening steel.

strengths when toughened (tempered) by reheating to 1000°F.

CHEMISTRY OF HARDENING STEEL

When steel is heated to the hardening temperature and cooled rapidly by quenching, it tends to retain the chemical structure present at the higher temperature. If a piece

of steel could be cooled instantly from above the critical range, the structure would be pure AUSTENITE. Except for some alloy steels, the steel cannot be cooled fast enough to retain the austenitic structure. Instead, other structures—MARTENSITE, TROOSTITE, and SORBITE—are formed.

Because you can't accurately determine or control the RATE of cooling, you can't determine the structure of hardened steel exactly. It's extremely difficult to obtain the desired structure with the hardening heat treatment. You can obtain better results by a controlled REHEATING process known as TEMPERING.

TEMPERING STEEL

Hardened steels are tempered to remove cooling strains and to make them SOFTER, TOUGHER, and more SHOCK-RESISTANT. This is accomplished by reheating the metal in order to change or transform the structure of the steel. These changes are explained by the diagram in figure 186.

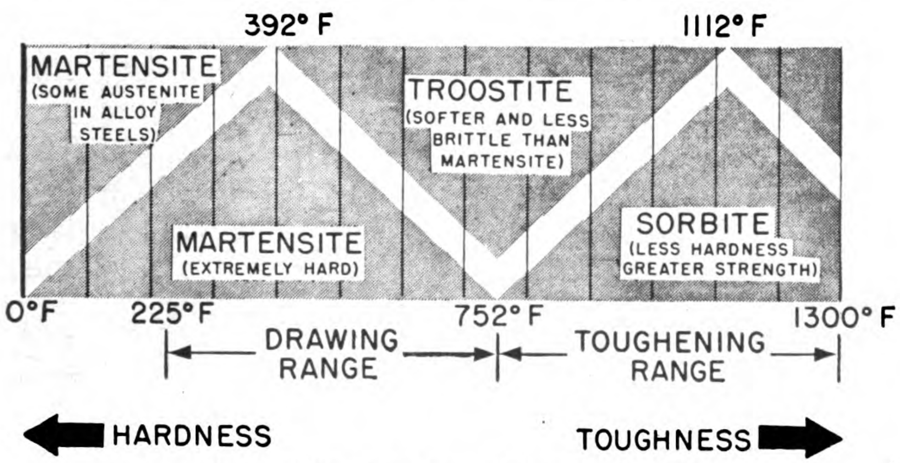


Figure 186.—Structure of tempered steel.

Tempering is divided into two classifications according to temperature used—

DRAWING is the name applied when the temperature does not exceed 752°F. Drawing removes just enough brittleness and hardness so the steel will not chip, crack, or shatter. Such tools as chisels, drills, punches, and hammers are drawn.

TOUGHENING is carried out at temperatures ranging from 752° to 1300°F. (usually 1000°F.). Hardness is sacrificed to obtain toughness and shock-resistance.

Levers, gears, shafts, and structural members are usually toughened.

The temper (structure) of a piece of steel depends on the length of heating time as well as on the temperature reached. Extremely slow heating or continued heating (soaking) at the tempering temperature will cause a more complete change in the structure than moderate or fast heating.

Notice in figure 186 that the structure of drawn steel is mostly martensite. It does contain some toostite as the temperature increases from 392° to 752°F. A toughened steel is mostly sorbitic in structure but it contains some troostite in the 752° to 1112°F. range.

Steel is usually quenched after tempering. This quenching is really a convenience rather than a necessity.

GRAIN SIZE CONTROL

Most of the steel you use will have a FINE GRAIN. If it is overheated, or soaked too long above 1350°F., the grain size will increase—the small grains combine to form large grains. A large-grain steel is easily machined but is weaker than a fine-grain steel.

Coarse-grained steel may be refined (grains made smaller) by a normalizing treatment. Forging processes also keep the grain fine—by breaking large grains into smaller grains and by retarding grain enlargements. That's one reason that forgings are so strong.

CASE-HARDENING

When a steel part must have an extremely hard, wear-resisting surface and a soft, tough core, it is CASE-HARDENED. Only low-carbon steels (carbon less than 0.20%) are case-hardened.

A hard case or shell is obtained by some method which ADDS carbon to the surface of the steel. This case or shell contains from .83% to 1.7% carbon and is seldom more than 1/8 inch thick. Several methods are used to increase the carbon content of the shell—

CARBURIZING is a process in which the steel part is packed in a steel box with a carbonaceous substance (wood charcoal, charred bones, or charred leather) and held at a high temperature (usually 1700° F.) for several hours. The longer it's heated the thicker

the case becomes. Some liquids and gases are used for carburizing but their use requires special equipment.

CYANIDING is a case-hardening process in which the steel part is heated in a bath of sodium or potassium cyanide. The temperature used is 1550° to 1600° F. and the time required only 10–15 minutes. Only a thin case is obtainable by cyaniding. The cyanide vapors are EXTREMELY POISONOUS. SPECIAL EQUIPMENT and adequate VENTILATION are essential.

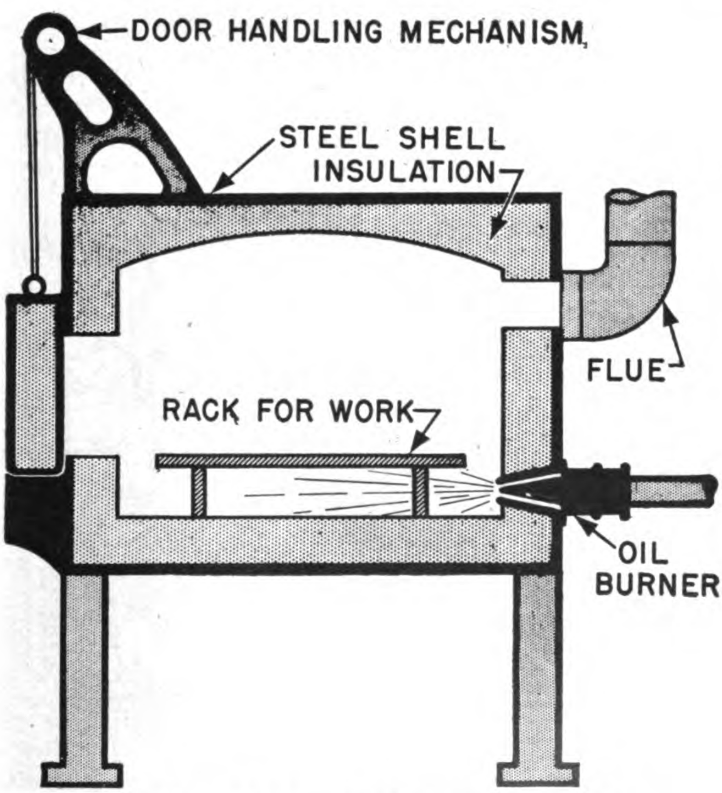


Figure 187.—Oil burning heat-treating furnace.

NITRIDING produces the hardest case but the process works only on alloy steels containing aluminum. The part to be treated is soaked in anhydrous ammonia for several days at a temperature of 1200–1300° F.

Case-hardened parts that have been carburized require further heat treatment. Usually they are—

Annealed at 1600° F. to refine the grain of the core metal.

Annealed at 1350° F. and quenched to refine the grain of the case metal.

Tempered to suit the job.

Here's how some of the S.A.E. steels are carburized—

X1020—Soak 8 hours at 1700° F. Cool in box. Reheat and water quench at 1625° F.

4320, 4620, 5120—Soak 8 hours at 1700° F. Cool in box. Reheat and oil quench at 1475° F.

4820—Soak 8 hours at 1700° F. Cool in box. Reheat and oil quench at 1450° F.

2315—Soak 8 hours at 1700° F. Cool in box. Reheat and oil quench at 1500° F.

HEATING EQUIPMENT

Various types of furnaces are used for heat-treating

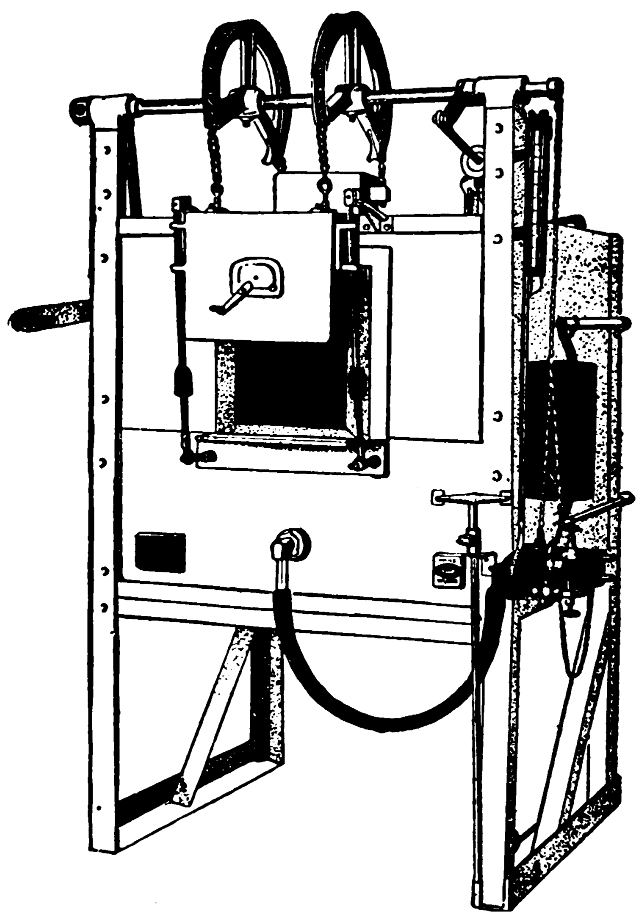


Figure 188.—Electric heat-treating furnace.

steel and other metals. Two of the commonly used general types are—

AIR FURNACES (oven type) are used for annealing and hardening, and also for tempering. These furnaces

must be well insulated and designed to heat uniformly. Gas, oil, or electricity are used as fuel. Figure 187 shows a sectional view of a simple oil-burning oven-type furnace. Figure 188 illustrates a common type of electric furnace.

BATH FURNACES (crucible type) are filled with oil, lead, or salt solutions. The metal is heated in these solutions. Temperatures for tempering steel are easily controlled with a bath furnace. High temperature work is impractical because the bath can't take the heat—it oxidizes or vaporizes and is lost.

For tempering, a SALT SOLUTION of half sodium nitrate and half potassium nitrate (or sodium nitrite) may be used. Such a solution is suitable for use in a furnace of the type shown in figure 189. Metal parts should be

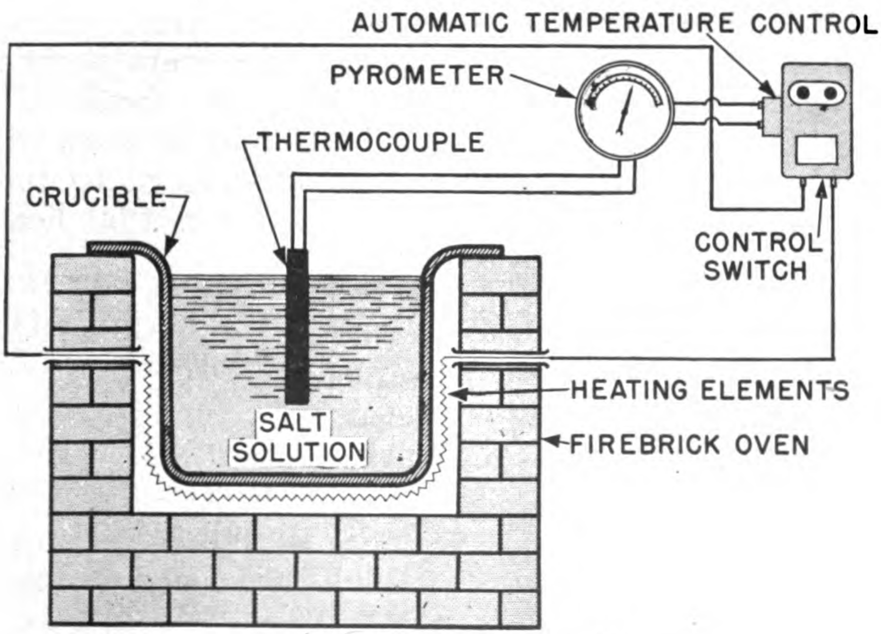


Figure 189.—Salt-bath furnace.

washed in clean water after tempering in order to dissolve and remove the corrosive solution.

TEMPERATURE CONTROL

Heat-treating furnaces are usually equipped with temperature-indicating devices which are calibrated in degrees Fahrenheit (F.) or Centigrade (C.) A THERMOCOUPLE is inserted in the contents of the bath furnace or

into the oven space of the air furnace and connected to an indicating PYROMETER (figure 190).

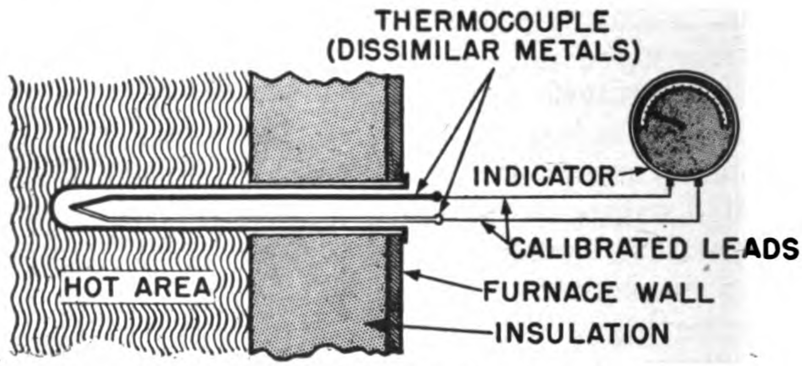


Figure 190.—Diagram of a pyrometer.

Larger furnaces usually have elaborate RECORDING PYROMETERS or POTENTIOMETERS. These instruments mark the temperature on a moving TIME SHEET. Other controls permit the temperature to be held at a certain point for soaking and thus prevent overheating of the metal.

If you are required to do some heat-treating work without using a regular furnace, you must learn to judge temperatures by COLOR. Here are the colors that heated steel assumes at various temperatures—

°F.	Color
900	Faint red
1,050	Blood red
1,075	Dark cherry
1,250	Medium cherry
1,375	Cherry or full red
1,550	Bright red
1,650	Salmon
1,725	Orange

Few heat-treating processes require more than 1,725° F. In fact, you will seldom use more than 1,550° F. (bright red).

TEMPERING TEMPERATURES (for drawing) can be estimated by the color of the oxide which forms on CLEAN steel. After you harden the steel, polish a portion of one surface with emery cloth and observe the color of that surface as you bring up the temperature for tempering. Here are the oxide colors you will see—

TEMPERING TEMPERATURES BY COLOR

F°	OXIDE COLOR	USE
400	Faint straw	Hammer faces, machine cutting tools
460	Dark straw	Taps and dies
480	Deep straw	Punches, reamers, dies, knives
500	Brown yellow	Twist drills
520	Bronze	Drift pins, punches
540	Purple	Cold chisels
550	Bluish purple	Screwdrivers, springs

In an emergency you can heat steel (for drawing) in a stove oven, in a baking oven, with a blow torch or welding torch, or in a wood, coal, or charcoal fire. Although uniform results are difficult to obtain under these conditions, an experienced workman can do a remarkably good job with makeshift equipment and a good eye for heat colors.

Non-ferrous metals may be heat-treated with the same furnaces used for steel.

FAHRENHEIT AND CENTIGRADE

Heat-treating temperature charts and tables may use Centigrade degrees, Fahrenheit degrees, or both. In any event you should be able to change one to the other.

The formula for changing Fahrenheit readings to Centigrade readings is—

$$\frac{5\ (°F - 32)}{9} = °C.$$

Now, suppose you want to change 500° F. to a Centigrade reading. Here's the way to use the formula—

First of all, SUBTRACT—

$$500 - 32 = 468$$

Then MULTIPLY—

$$5 \times 468 = 2340$$

Now DIVIDE—

$$2340 \div 9 = 260$$

Your answer is 260° C.

The formula for changing Centigrade readings to Fahrenheit readings is—

$$\frac{°C \times 9}{5} + 32 = °F.$$

Suppose you needed to change 800° C. to ° F. Do it this way—

First, multiply—

$$800 \times 9 = 7200$$

Then divide—

$$7200 \div 5 = 1440$$

Add—

$$1440 + 32 = 1472$$

Your answer is 1472° F.

HOT METAL

Any metal in or around a heat-treating shop should be considered as HOT metal. EMPTY (?) guns have killed plenty of people and COLD (?) metal has burned plenty of skin.

Asbestos gloves, with leather palms and long gauntlets, will protect your hands and arms when you're handling hot metal. Wear a pair of clear safety goggles to protect your eyes from heat and flying sparks and scale.

PLAY SAFE WITH HEAT—bandages are a sign of carelessness.

CHAPTER 14

NON-FERROUS METALS

WHAT ARE THEY?

All metals not classified as iron and steel (ferrous metals) are known as NON-FERROUS metals. You're familiar with the names copper, lead, tin, zinc, aluminum, and nickel. These metals—and their alloys—are all classified as non-ferrous metals. And you're also acquainted with some of the alloys—brass, bronze, and solder in particular.

PROPERTIES DETERMINE USES

The properties of non-ferrous metals are judged and determined by methods similar to those used for iron and steel. The same terms are used—ductility, malleability, hardness, toughness, tensile strength, shock resistance, etc. A metal is selected for a specific use in terms of the properties it possesses.

Generally speaking, the non-ferrous metals are superior to iron and steel for corrosion resistance, electrical conduction, and ease of working. Because of scarcity and the greater cost of manufacturing, most non-ferrous metals are more expensive than steel. Only a few of the stronger bronzes approach the strength of the better grades of steel.

As a Metalsmith you will use non-ferrous metals in the form of sheet stock, strips, rolled shapes, pipe, tubing and forging. Also, you may do some repair work on non-ferrous metal castings.

IDENTIFICATION

Pure non-ferrous metals are easily identified by COLOR. Non-ferrous alloys are more difficult to identify because color may not be greatly affected by a change in alloy composition.

The grinder spark test won't work with non-ferrous metals (except nickel) because these metals don't spark when ground. Nickel makes a short straight spark with an orange color.

Because the non-ferrous metals have different melting points, they may be identified by the temperature at which they begin to melt. A high temperature thermometer, called a PYROMETER, may be used to measure the heat of the metal at its melting point.

IDENTIFICATION OF NON-FERROUS METALS

	COPPER	ALUMINUM	LEAD	ZINC
Surface Color (Polished)	Bright copper red	White	White	Bluish white
Surface Color (Unfinished)	Reddish-brown to green	Light gray almost white	Gray	Dull gray
Color of Break	Red	White	White crystalline	Bluish white, bright
Melting Point	1981° F.	1220° F.	621° F.	787° F.
Weight in pounds per cubic foot	560	170	700	445

Figure 191.—Identification of non-ferrous metals.

Use the table in figure 191 as an identification guide for the non-ferrous metals which are often used without alloying.

Metals are often indicated by symbols. Here are the symbols for nine of the common metals—

Copper	(Cu)	Iron	(Fe)	Aluminum	(Al)
Tin	(Sn)	Zinc	(Zn)	Nickel	(Ni)
Lead	(Pb)	Magnesium	(Mg)	Silver	(Ag)

COPPER

As a useful metal, COPPER is outranked only by steel. Commercially pure copper—99.9 percent pure—is obtainable in the form of wire, rod, tube, sheet, and strip. It has good resistance to salt water corrosion—so good that metals of lower resistance to corrosion are often coated (plated) with pure copper. Don't be fooled by the tarnished green color of weathered copper. The tarnish is only on the surface and does not materially damage the copper.

Copper is comparatively soft. It is also malleable and ductile. Because of these properties and its excellent electrical conductivity, it is used to make electrical wire and parts of motors, switches and generators. Wire is made of copper and other ductile metals by a hot or cold "drawing" process. See figure 192. The wire is usually cold for the final "pass" or "draw".

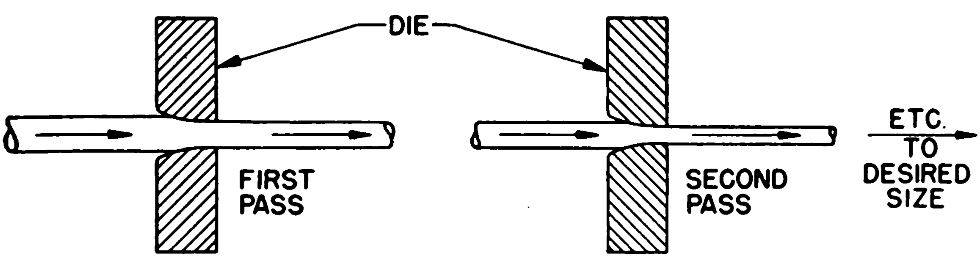


Figure 192.—"Drawing" wire.

Copper may be annealed by heating it to a cherry red color. The copper is fully annealed to maximum softness at a temperature of 1375° F. It softens appreciably at much lower temperatures. After heating, the copper may be quenched in water or allowed to cool in still air. Repeated annealing does not appear to cause any damaging effects.

Metalsmiths anneal a lot of copper tubing. Plain tubing is annealed at 1150° F. Tubing that has been silver-soldered should be annealed at 875°—never above. Fit-

tings on flared sections may be slipped to one end while the other end is being annealed. Clean the tubing thoroughly after annealing. The scale caused by the heat can be removed by placing the tubing in a pickling solution of three parts water and one part sulfuric acid. When the tubing is clean, remove ALL TRACES of the acid by washing the tubing in fresh water. Make sure that ALL the acid is removed and that the inside of the tubing is perfectly clean.

Copper sheets may be fastened with seams and rivets and then soldered with soft solder. Stronger joints are made by brazing with silver solder or brass (copper alloy). Laps and seams must be pre-tinned for sweat soldering. If soldering coppers are used they should be large, as the base metal conducts the heat rapidly.

Copper can be hardened only by cold working (rolling or hammering)—it CANNOT be hardened by heat treatment.

If used together, copper and zinc sheets, or copper and zinc-coated sheets, must be insulated to prevent galvanic action between the metals.

ZINC

ZINC is a bluish-white metal that is somewhat less ductile and malleable than copper. Its tensile strength is low and it becomes extremely hard when worked. Sheets are bought in the conditions of DEAD SOFT, SOFT, HALF-HARD, and HARD. The "grain" of hard sheet zinc is distinct. Bends made along the grain should have large radii in order to prevent fracture. The principal use of zinc is to combine it with copper to make the alloy BRASS.

LEAD AND TIN

Lead, one of the heavier metals, is very malleable, plastic, and corrosion-resistant. It lacks hardness and strength. Aboard ship, lead is used as a lining for steel and iron pipe, cold compartments, and acid tanks and containers. Some pipe is made entirely of lead. But don't use lead on food-handling equipment—it's POISONOUS.

Tin is seldom used "as is." It is a valuable alloying agent. Mixed with lead, tin forms solder, and mixed with copper it makes bronze.

The properties of lead and tin are similar as regards corrosion-resistance but the tin has the advantage of being non-poisonous. Tin is often used to coat cooking and food-handling equipment and the inside of piping used to convey drinking water.

Lead may be soldered with tallow used as a flux but is more easily joined by a method known as "lead burning," which is similar to welding. This method requires a small tip and a soft flame. When using this method, a strip of lead is used as a filler. Lead joints must be scraped clean and bright before they are either soldered or burned. Avoid breathing the fumes from hot lead or you'll be in sick bay with LEAD POISONING. And after you've handled lead, always wash your hands before you eat or handle food.

BRASS

A TRUE brass is an alloy of copper and zinc. COMPLEX brasses are those containing additional alloying agents—aluminum, lead, iron, manganese or phosphorous. NAVAL ROLLED brass is about 60 percent copper and 40 percent

BRASS

	PERCENT OF ALLOY ELEMENTS			
KIND OF BRASS	COPPER	ZINC	TIN	LEAD
Naval rolled	60–61	38–39	1.0	0.05
Commercial rolled	60–70	30–40	Some	Impurities
Cartridge or Spinning	65–73	27–35	....	....
Yellow (Cast)	62–73	25–35	....	2.0–3.0
Med. red (Cast)	72–87	8–15	2.0–3.0	7.0–10
Composition F (Cast)	85	15.0	....	....
Red (Cast)	85	5.0	5.0	5.0
Muntz metal	54–60	40–46	....	....

Figure 193.—Content of brass alloys.

zinc and is practically free of impurities—it has to be to resist corrosion.

BRASS SHEETS and strips are available in SOFT, 1/4 HARD,

½ HARD, FULL HARD, and SPRING grades. The hardness is accomplished by cold rolling. All grades of brass can be made softer by annealing at a temperature of 550 to 600° F. The brass should be allowed to cool by itself—no quenching. Do not overheat it or you may destroy the zinc in the brass.

Soldering of brass is easily done. Cut acid is the best flux to use. Brass should be handled much the same as copper when you are soft-soldering, silver-soldering, or brazing.

For forming, brass may be heated to about 200° F. Heated brass is easier to form and less apt to break or crack.

BRASS CASTINGS are used extensively by the Navy. These castings are of several different alloys. Some of these and other brasses are listed, with their alloy contents, in figure 193.

Terms you may see or hear—

ALPHA brasses are any containing up to 39% zinc.

BETA brasses contain more than 39% zinc. They are less ductile and malleable than alpha brasses. Muntz metal is a beta brass.

HIGH brasses is a term applied to those with over 20% zinc.

LOW brasses have less than 20% zinc.

BRONZE

Before steel-making techniques were discovered, a bronze made of 84% copper and 16% tin was the best available metal. A thousand years ago bronze tools and weapons were the best to be had. And the first good naval cannon (guns were called cannon in those days) was made of bronze some five hundred years ago.

Although bronze was originally an alloy of copper and tin, many COMPLEX alloys containing three or more elements have been developed. Therefore, there is now no distinct line between brass and bronze. In fact, commercial bronze (used for hinges and other hardware) is really a low brass containing 90–95% cooper and 5–10% zinc.

You won't have much occasion to use bronze in sheet form but you may be required to work on castings.

PHOSPHOR BRONZE is a type you may use in sheet or strip form. It's used to make springs, bearings, diaphragms and other parts that must resist wear and fatigue. In the annealed condition, phosphor bronze has a tensile strength of 40,000 psi. Cold working increases this to 125,000 psi.

SILICON BRONZES were further developed during World War II because of the scarcity of tin. They are as strong as low-carbon steel and have high corrosion resistance. Many castings used on ships are cast of silicon bronze.

ALUMINUM BRONZES are also highly resistant to corrosion and relatively strong. They may be softened by heating to 1500°–1600° F. and quenching. They may be hardened by heating to 700°–1100° F. and cooling slowly.

Some of the commonly used bronzes are listed in figure 194, along with their alloy content. Remember that the bronzes are generally used for castings.

KIND OF BRONZE	PERCENT OF ALLOYING ELEMENTS			
	COPPER	ZINC	TIN	LEAD
Commercial	90–95	5–10	..	..
Bearing	80	....	10	10
Tobin	60	38	2	..
Phosphor	87	2.3	10	.7% Phos.
Aluminum	95	5% Aluminum		
Silicon	95	3% Silicon, 2% other elements		

Figure 194.—Kinds of bronze.

Brazing rods and spelter are made of copper alloys. These alloys are selected and made up to provide alloys with somewhat lower melting points than those of the metals being joined. Spelter is available as rod, grains, or powder.

COPPER-NICKEL ALLOY

COPPER-NICKEL tubing containing 70% copper and 30% nickel is used extensively in the construction of Navy

ships. This tubing is used to convey salt water because it is highly resistant to electrolysis or galvanic action. Although copper-nickel resembles nickel in color and must be worked COLD, it has the general working characteristics of copper.

Copper-nickel melts at 2200° F. You can anneal this alloy by heating it to 1450° F. and allowing it to cool in still air. Copper-nickel is a poor heat conducter. It takes silver-soldering much better than welding. Grades III and IV silver solder are used normally. A thick paste flux is required for silver-soldering.

NICKEL ALLOYS

MONEL contains from 65 to 68% nickel, about 30% copper, and small percentages of iron, manganese and cobalt. In appearance monel resembles stainless steel. In fact, it has many of the same qualities as stainless steel.

Monel is harder and stronger than either nickel or copper. It also has good ductility. Monel has a very high resistance to corrosion and is so strong it may be substituted for steel where corrosion resistance is of primary importance. These excellent qualities make it valuable for such uses as pump parts, turbine blades, table tops, laundry equipment, steam valves, containers, and head fixtures and equipment. Nuts, bolts, screws, control parts, and other fittings are also made of monel.

Monel can be worked cold. It also can be forged and welded. Monel should never be worked at temperatures between 1200°F. and 1600°F. It becomes "hot short" (brittle) when forged in this temperature range. Monel cannot be hardened by heat treatment. Cut acid is used as a flux for soft-soldering monel. Seams must be pretinned for sweat soldering. Joints that must be strong are silver-soldered.

K-MONEL is a special improved type of alloy that has greater strength and hardness. Its strength is comparable to that of heat-treated steels. K-monel is used for instrument parts that must resist corrosion.

INCONEL is a high-nickel alloy containing 78½% nickel, 14% chromium, 6½% iron and about 1% of other elements. It has great resistance to corrosion and retains its strength at high temperatures. Exhaust systems of engines are often made of inconel.

ALUMINUM AND ITS ALLOYS

ALUMINUM is being used more and more in ship construction because of its light weight, easy workability, good appearance, and other desirable properties. Pure aluminum (over 99 percent pure) is soft, ductile, and malleable. It's seldom used alone in the pure state because pure aluminum is not hard enough nor strong enough for structural purposes. Aluminum is improved by the addition of other elements to form alloys.

ALUMINUM ALLOYS containing silicon, magnesium, copper, nickel, and manganese have been developed by metallurgists. The aluminum content of these alloys is usually 90% or more. The alloys are used to make parts of planes, engines, railway coaches, outboard motors, electrical appliances, and many other products. Some of the aluminum alloys are stronger than mild steel, although pure aluminum is only about one-fourth as strong as steel.

DURALUMIN was the name given to one of the first strong structural aluminum alloys. Now there are so many different alloys that they are designated by NUMBERS (2, 3, 4, 17, 24, 52, etc.) that indicate the CONTENT of the aluminum alloy. LETTERS SYMBOLS are used to indicate the method of manufacture and the cold-worked or heat-treated CONDITION of the metal.

WROUGHT ALLOYS—those used for rolling, pressing, and hammering—are indicated by an *S*. CASTING ALLOYS are indicated by a *B*. Pure aluminum is classified as 2S. The alloy formerly called duralumin is now classified as 17S–T. (The T means the metal is heat-treated.)

NON-HEAT-TREATABLE wrought aluminum alloys such as 3S, 4S, and 52S may be hardened by cold-working—they cannot be hardened by heat treatment. The following markings (used here with 3S alloy) are used to indicate the hardness of the non-heat-treatable alloys—

SYMBOL	CONDITION
3S–0	= dead soft (annealed)
3S–¼H	= one-quarter hard
3S–¼H	= one-quarter hard
3S–¾H	= three-quarters hard
3S–H	= hard

HEAT-TREATABLE ALLOYS such as 17S, 24S, 53S, and 61S may be hardened by proper heat-treatment and age-hardening. They may be further hardened by cold-working. The hardness of these wrought alloys is indicated by the following symbols, used here with the 17S alloy—

SYMBOL		CONDITION
17S–T	=	heat-treated and age-hardened.
17S–RT	=	heat-treated, age-hardened, and strain-hardened (usually by rolling). This is the hardest condition of an alloy.
17S–W	=	heat-treated but not age-hardened.
17S–O	=	annealed (A may be used instead of O).

You may use some of the aluminum alloys in sheet form to make and repair lockers, shelves, furniture, boxes, trays, and other containers. Sheet stock is usually labeled with its proper symbol and with its thickness in thousandths of an inch.

Sheet aluminum alloy used for new Naval construction is usually specified as 52S (Navy Spec. 47A11) for sheets up to .102 inch thick and 53S (Navy Spec. 47A12) for thicker sheets and plates. The content of these two alloys is shown here—

ALLOY	NAVY SPEC.	SILICON	MAGNESIUM	CHROMIUM
52S	47A11	..	2.5%	0.25%
53S	47A12	0.7%	1.3%	0.25%

The remaining 97° – 98° is aluminum and allowable impurities.

Bars, rods, shapes, and wire are made of 53S stock (Navy Spec. 46A10). Rivets made of 53S stock are used with both 53S and 52S sheets and shapes. The rivet specification number is 43R5, Grade E. These rivets should be used as received.

USING 52S AND 53S STOCK

Aluminum alloy of the 52S type CANNOT be hardened by heat-treatment, but 53S may be heat-treated and age-hardened.

Both 52S and 53S may be welded but 53S should be in the soft ("O" or "A") condition. Both alloys may be spot-

welded. The results are generally unsatisfactory when soldering is attempted.

Aluminum alloys should not be exposed to salt water or used in any damp place. They should never be installed in close contact with steel or with copper alloys because an undesirable, corrosion-producing, electrical current is set up. Suitable insulating materials—fiber, rubber, or composition—should be installed between the dissimilar metals. The metals may be insulated by coating the contacting surfaces with ZINC CHROMATE paint. This type should be used because it has the desired characteristics.

Threaded parts made of aluminum alloys should fit loosely and be coated with an "anti-seize," corrosion-preventing compound to prevent "freezing" (sticking caused by corrosion).

Pure aluminum resists corrosion well, but the alloys soon corrode unless properly protected. The content of the alloying agents determines, to some extent, the rate of corrosion. ZINC CHROMATE is one of the best protective coatings for aluminum surfaces.

ALUMINUM CASTING ALLOYS

Special aluminum alloys for casting contain from 4% to 13% copper. Most of them have about 1% silicon, 1% iron, and smaller quantities of other alloying elements.

Casting alloys are classified as HEAT-TREATABLE (designated as B–21, B–22, and B–23) and NON-HEAT-TREATABLE (B–12, B–13, and B–14).

As a Navy Metalsmith you may repair aluminum castings by welding cracks and breaks.

BEARING METALS

Bearing metals are alloys of copper, tin, lead, zinc, antimony, and iron. The first three may be used either alone or in combination with any of the last three. Alloys are concocted to fit different types of bearings—no one alloy can meet the specifications for all types of poured bearings.

BABBIT METAL is a general-purpose white bearing alloy. It usually contains 85% tin, 10% antimony, and 5% copper. This alloy is stronger, harder, and lighter than the cheaper lead-base alloys.

SILVER SOLDERS

Silver solders are made up principally of silver and copper. The silver solder which melts at the lowest temperature (1160°F.) contains 72% silver and 28% copper.

Silver solder is used extensively on naval installations made of copper and copper alloys. Its melting point is safely below those of copper, brass, monel, and bronze. It has good ductility—it can be bent and shaped with the metal to which it is applied. Silver solder is practically non-corrosive.

You'll find more information about silver solder in Chapter 6 of this book.

CHAPTER 15

FIRE FIGHTING

SAVE THE SHIP!

When the ship puts out on a mission, all hands must do everything they can to—

KEEP THE SHIP AFLOAT.

KEEP THE SHIP UNDER WAY.

KEEP THE GUNS FIRING OR READY TO FIRE.

PROTECT THE LIVES OF CREW.

Your normal routine as a Metalsmith contributes to the accomplishment of these purposes. But you have a SPECIAL duty when fire, accident, or enemy action threaten the safety and fighting ability of your ship and her men. When that happens, you'll have to swing into action as a member of a FIRE FIGHTING PARTY or a DAMAGE CONTROL PARTY.

The causes of damage to a ship are divided into two general classes. One is FIRE; the other class includes ENEMY ACTION, WEATHER, COLLISION OR OTHER ACCIDENT.

You may encounter both kinds of trouble at the same time. Regardless of the nature of a casualty, fire is likely to follow. Unless the fire is extinguished speedily and effectively, it can cause more serious damage than that resulting from the initial casualty. It's best, however, to study separately the methods used against fire (which

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may or may not damage the ship's structure), and those used against damage to the ship's structure from other causes. So you'll find the major points of Navy firefighting discussed in this chapter, and some highlights of damage control in the next chapter.

KINDS OF FIRES

Different types of fires are combatted by different means—a SOLID STREAM of water; a fine spray of water called FOG; a FOAM created from chemicals; a combination of fog and foam; CARBON DIOXIDE (CO_2); or STEAM. If you understand "which to use when," you'll have a clearer idea of the purposes of the various kinds of fire-fighting gear.

Fires have been classified by the Navy into three general kinds—

CLASS A FIRES are those in ordinary combustible material: bedding, clothing, wood, canvas, rope, paper. To extinguish such fires, USE PLENTY OF WATER. COOL and SOAK the burning material to extinguish all embers and prevent re-ignition of the material.

CLASS B FIRES are fires of flammable liquids, such as gasoline, paint, oils, or turpentine. These fires are best put out by a SMOTHERING OR BLANKETING ACTION. Foam, carbon dioxide, steam, and fog are effective in smothering Class *B* fires.

CLASS C FIRES are those which involve electrical equipment. Because there is danger of electrical shock when fighting this type of fire, the extinguishing agent should be a "non-conductor." Carbon dioxide (CO_2) is first choice for electrical fires, because it is a non-conductor and does not cause damage to electrical equipment. Fog is second choice for Class *C* fires, but it's harmful to electrical gear, and as a conductor it is dangerous to personnel.

FIRE-FIGHTING EQUIPMENT

The principal kinds of fire-fighting equipment (some INSTALLED, some PORTABLE) include these—

Fire main system.
All-purpose fire nozzles.
Foam equipment.

Fog sprays.
CO_2 extinguishers.
Handy billy and other pumps.
Oxygen rescue-breathing equipment, including hose (air-line) mask, and asbestos suits.

Do you know where this equipment is located? How it is operated? How it works? Why it works? If not—FIND OUT. It's your job to KNOW!

FIRE MAIN SYSTEM

You should get acquainted with the fire main system THROUGHOUT THE SHIP—the location of the fire main proper, and the "riser" piping which carries water to the upper decks; of the plugs where hoses can be attached to the mains; of the pumps, valves and controls.

The fireplugs have outlets either 2½ inches or 1½ inches in diameter. Some plugs are equipped with wye-gates, shown in figure 195, which provide two outlets, each 1½″ in size. In some cases, a reducing fitting is used so that a 1½″ hose can be attached to a 2½″ outlet.

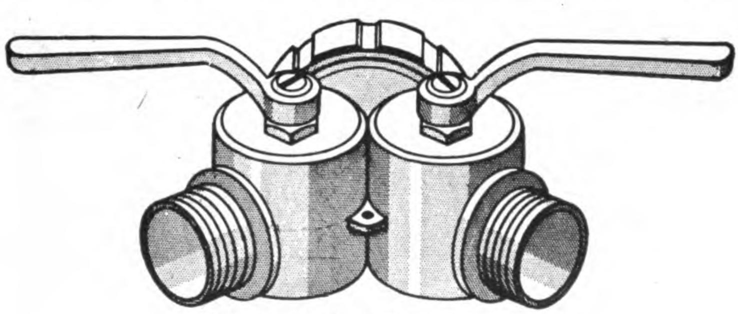

Figure 195.—A wye-gate.

Connected to the fire plugs, and stored in adjacent racks, you will find two lengths of either 1½″ or 2½″ hoses. The 1½″ hose is used on smaller ships, and below decks on larger ships. This hose is made up in 50-foot lengths, with the necessary end couplings. All threaded parts of fire hose fittings and couplings have standard threads. They are easy to connect. Hose and fittings 1½″ and below have standard pipe threads; those 2½″ and over have standard Navy hose threads.

Two men working together can make up a fire hose in a hurry. You can do the job alone if you place the hose on the deck and hold it down with your foot JUST BEHIND THE FITTING. The pressure of your foot will cause the

metal fitting on the end of the hose to point upward, so that you can screw in the nozzle or other fitting.

When you are connecting threaded parts, first take a half-turn to the LEFT to set the threads. Then turn to the right until the joint is tight. PRACTICE THIS TECHNIQUE. A fumble will cause unnecessary delay at a critical time.

Fire hose is usually faked on a bulkhead rack near a fireplug. Nozzles, extensions called applicators, and spanner wrenches are racked on the bulkhead near the hose.

ALL-PURPOSE FIRE NOZZLES

The Navy's new all-purpose fire nozzle can produce either fog or a solid stream of water. This type of nozzle is available for both 1½″ and 2½″ hose. It can be adjusted or shut off quickly and easily by means of the handle illustrated in figure 196.

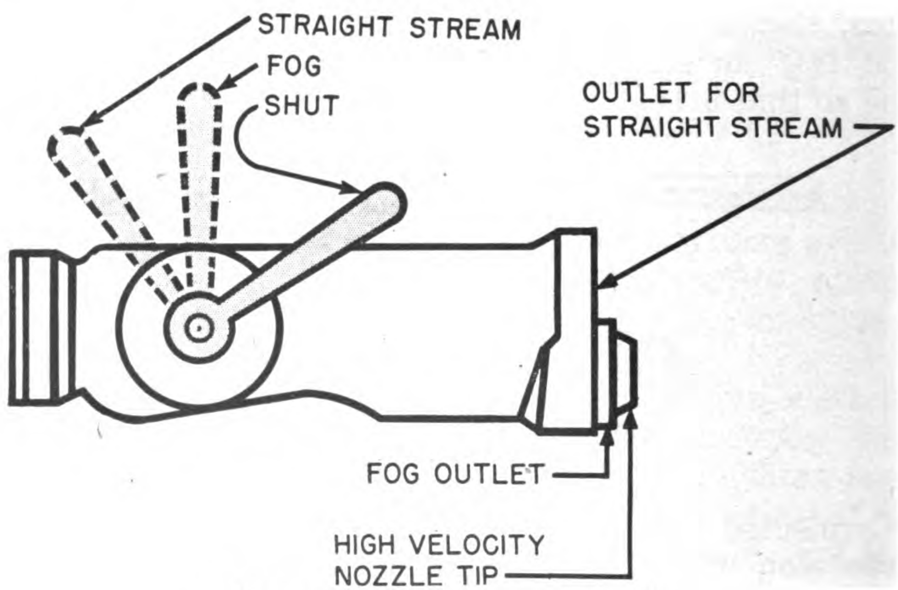

Figure 196.—The all-purpose nozzle.

As indicated in figure 196, fog comes through an outlet in the lower part of the nozzle. When a straight stream is used, the water shoots out of the upper part, above the fog outlet.

The all-purpose nozzle is usually set to produce a HIGH-VELOCITY FOG, as shown in figure 197. For this use, a removable high-velocity nozzle tip is installed in the fog outlet.

For a LOW-VELOCITY FOG, remove the high-velocity noz-

zle tip and replace it with an APPLICATOR which is equipped with a FOG HEAD. Three applicators, and the nozzles with which they may be used, are shown in figure 198. With this set-up, you can still get a solid stream of water by positioning the nozzle control handle, as indicated in figure 196.

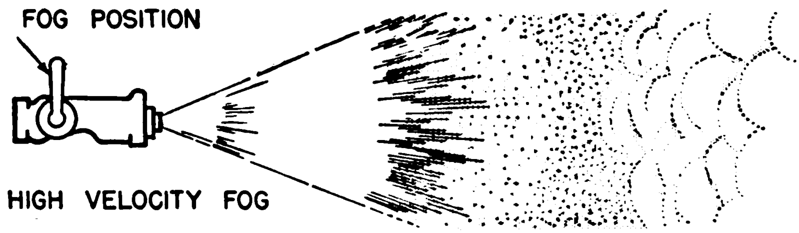

Figure 197.—High-velocity fog.

FOAM DEVICES

Foam fire-fighting devices generate either CHEMICAL or MECHANICAL foam. Chemical foam is produced by mixing a powder and water in a hopper-type mixer. Mechanical foam is produced by a liquid preparation which is mixed with water at the nozzle or in a duplex proportioner. In

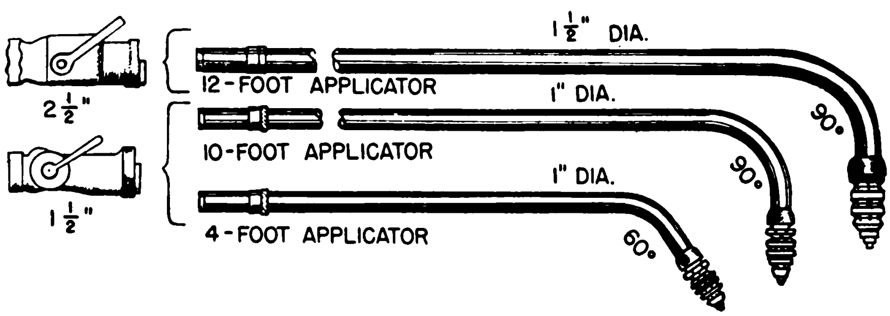

Figure 198.—Standard applicators.

BOTH cases the foam is made with chemicals. The difference is that the mechanical device, by means of its nozzle, adds air to the chemicals. The chemical foam device does not add any air.

CHEMICAL FOAM EQUIPMENT

The Navy has three devices which produce CHEMICAL FOAM—

Double 20-gallon (Twin-Twenty) cylinder unit (installed).

Continuous-type generator (portable or installed).

Accumulator, or pressure operated generated (installed).

Figure 199 shows one of the "TWIN-TWENTY" units. The two cylinders are installed and used together as a

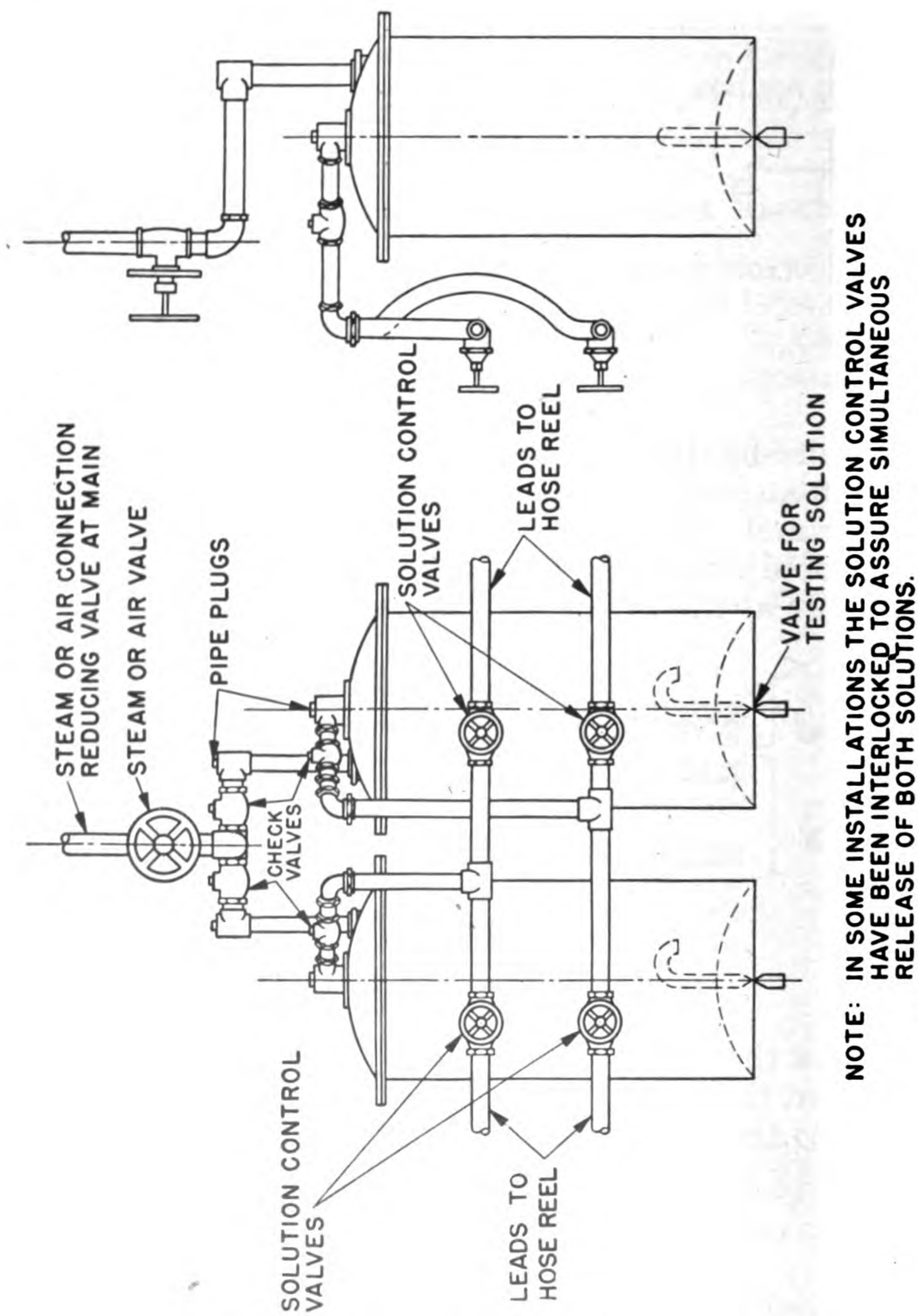

Figure 199.—Twin 20-gallon cylinder unit for chemical foam.

unit. One cylinder holds Solution No. 1 (aluminum sulfate) and the other holds Solution No. 2 (bicarbonate of soda and "foam ingredient"). Each cylinder has three

openings at the top—one for filling, one for discharging the contents, and one for admitting steam or air under pressure. The small outlet at the bottom of each cylinder is for drawing off samples of the solution for testing.

Each Twin-Twenty unit will serve either of two hoses. Notice in figure 199 that there are two pairs of leads, each set going to a different hose reel. For example, the leads on the right may serve a reel located in the same room with the foam device, and the leads on the left may go to an adjacent room. The solution control valves (also called discharge valves) are turned to discharge the foam to the desired hose.

The operation of the twin-twenty unit is simple. All you have to do is man the hose nozzle, open the CONTROL (DISCHARGE) VALVES, and then open the STEAM or AIR VALVES. A pressure of 75 psi throws a stream about 20 feet. To cut off the stream, just close the valves.

The CONTINUOUS-TYPE FOAM GENERATOR consists of an open hopper with an ejector at the bottom. Fifty-pound containers of dry chemical foam mixture are emptied into the hopper, one after the other as you fight a fire. A stream of salt or fresh water under a pressure of 75 to 100 psi passes through the ejector, where it picks up the foam chemicals. From the ejector the stream of water containing chemicals passes through a 2½″ hose line that should be at least 100 feet long for thorough mixing. The outlet end of the hose has a nozzle that is 1¾″ in diameter.

The continuous-type generator uses approximately 100 pounds of foam chemical per minute, which makes about 800 gallons of foam. The ejector is designed so that the passing stream of water will draw the proper quantity of foam chemical into the stream regardless of the water pressure.

The ACCUMULATOR-TYPE generator is no longer widely used on Navy ships.

MECHANICAL FOAM EQUIPMENT

The Navy also uses three devices which produce MECHANICAL FOAM for fighting fires—

Duplex pressure proportioner (portable or installed).

Straight-type pick-up tube proportioner (portable, with pick-up tube attached directly to nozzle).

S-type proportioner (for use with gasoline handy billy pump).

Each of these devices uses a MECHANICAL-FOAM NOZZLE. This nozzle, shown in figure 200, has a 21″ piece of flexible metal or asbestos composition hose. It is 2″ in diameter, has a solid metal nozzle outlet, and has a suction chamber and air port in the butt end. The foam that is discharged is a mixture of water, liquid-foam solution, and air. The flexible pick-up tube seen in figure 200 is attached to the nozzle, at the location indicated, in two of the three types of mechanical foam devices.

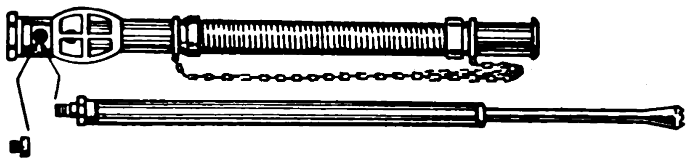

Figure 200.—Mechanical foam nozzle and pick-up tube.

One of the most common fire fighting devices aboard ship is the DUPLEX PRESSURE PROPORTIONER. It is an installed or portable duplex cylinder which holds a mechanical foam solution that is added—IN THE PROPER PROPORTION—to the water stream. See figure 201.

The cylinder is divided into UPPER and LOWER chambers so that one can be refilled while the other is being used. Notice, in the left part of figure 201, that there are two sets of filling shafts, water shafts and syphon tubes—one set extending into the lower compartment and the other set extending only into the upper compartment. Water under 75 to 100 psi pressure is admitted to a manifold located at the top of the cylinder, where it exerts pressure on the foam solution. The solution is forced up through a narrow syphon tube from the bottom of the compartment in use to the top of the cylinder. Just enough of this solution is fed into the stream to produce a good foam. This proportioning of the flow gives the device its name.

Here is the operating procedure.

Locate the proportioner (if it's portable) near the scene of the fire. Make the necessary line connections for supply and discharge. Man the nozzles. Open the WATER VALVE on the cylinder and keep the PROPORTIONING VALVE

HANDLE in a vertical position. After you turn on the water valve, wait until the PRESSURE GAGE of the cylinder reads at least 75 psi. Then throw the proportioner valve

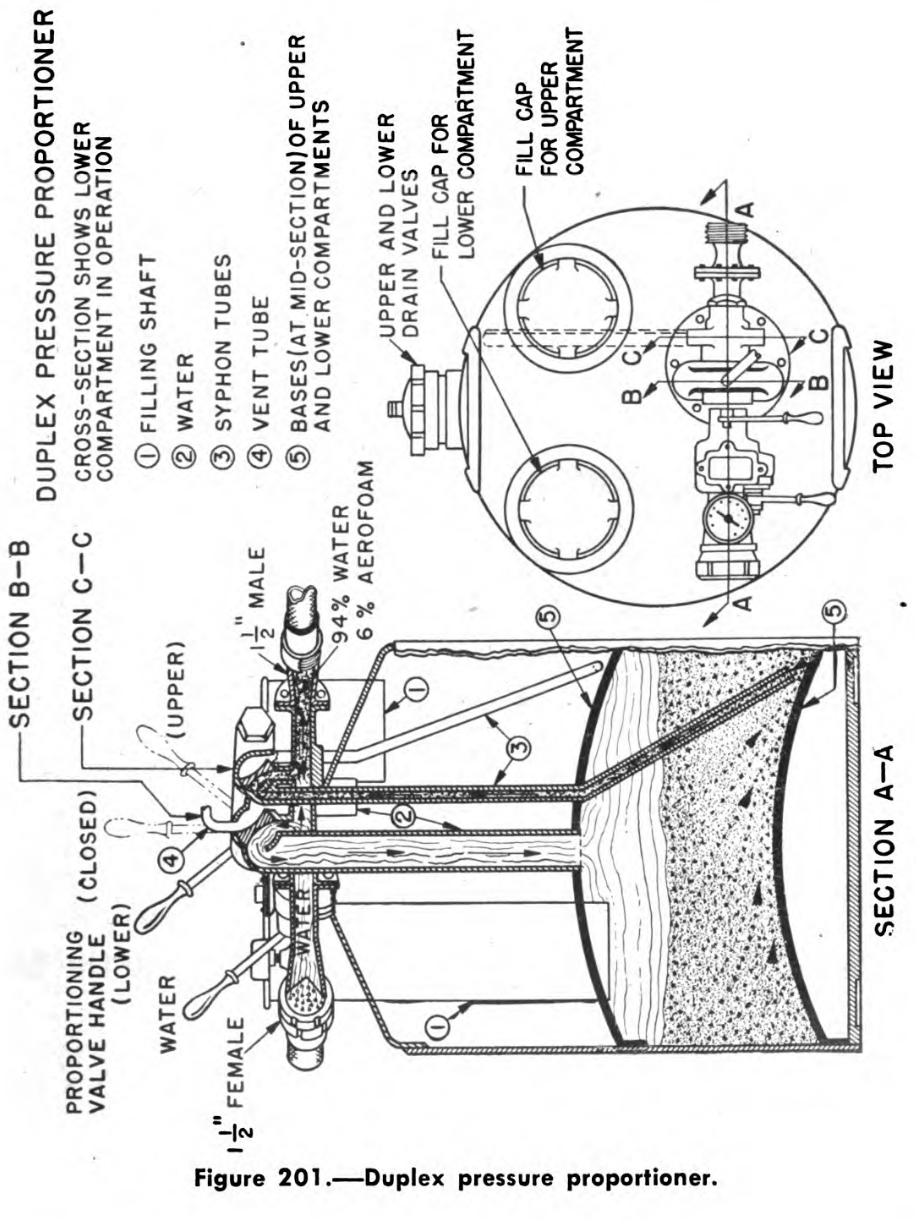

Figure 201.—Duplex pressure proportioner.

either to the RIGHT or LEFT (upper or lower compartment) and start the TIMER.

When the timer rings, indicating that one compartment is almost used up, switch to the other compartment, reset the timer, and refill the empty compartment.

To refill, remove the DRAIN CAP and the FILL CAP of the empty compartment. When the compartment is drained,

replace the drain cap and pour in two cans of foam liquid. Replace the fill cap, and the refilled compartment is ready for use. By repeating this process, the outfit can be used continuously as long as refills are available.

The other two mechanical foam devices make use of a PICK-UP TUBE, which is a short piece of ⅝″ pipe with a short length or rubber hose in one end. Figure 202 shows the arrangement by which the pick-up is joined to the mechanical foam nozzle in the STRAIGHT-TYPE PICK-UP TUBE PROPORTIONER.

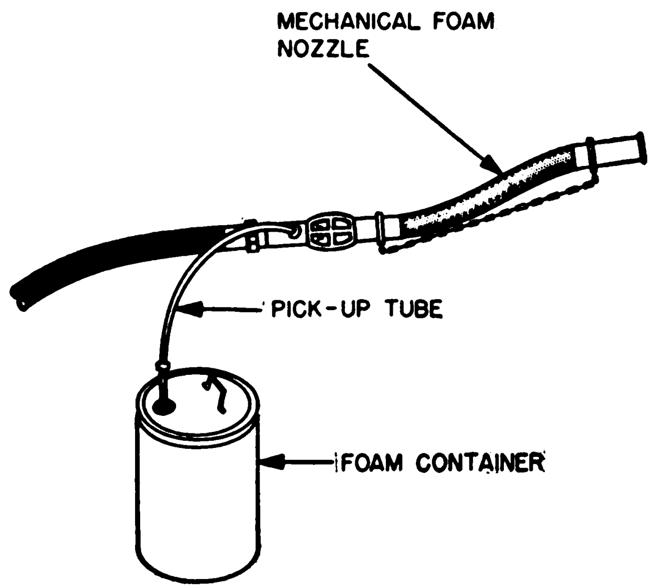

Figure 202.—Straight-type pick-up tube proportioner.

To operate—

Screw the nose end of the pick-up tube into the butt of the nozzle.
Man the mechanical foam nozzle.
Turn on the water at supply source.
Insert the metal end of the pick-up tube into a container of mechanical foam solution.
Push it to the bottom and hold it down firmly.
When the container is nearly empty, take out the pick-up tube and insert it into a full container.

The pick-up is also used by proper attachment to a handy billy pump. See figure 203. In this system (S-TYPE SUCTION PROPORTIONER) the foam-liquid is drawn into the suction chamber of the handy billy and forced into the water stream.

To operate—

Close the cock on the pump to "Prime" or "Water" position. Keep it there until the pump is primed and the water pressure reaches 100 psi or more. Then turn the cock to "Foam" position and set

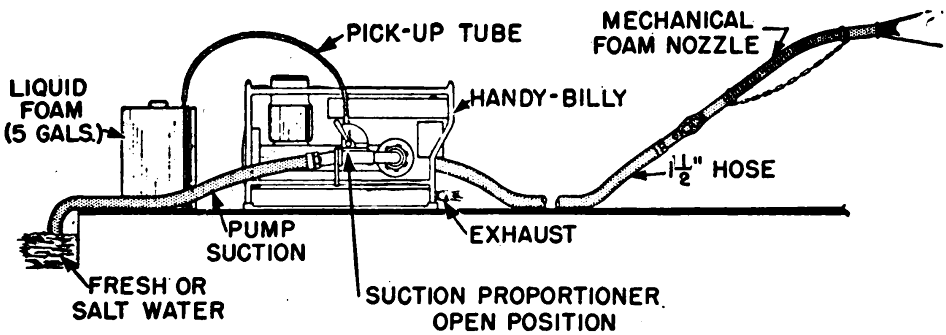

Figure 203.—S-type suction proportioner.

the pointer to the estimated lift (the number of feet) from the water supply level to the pump.

When the foam solution container is almost empty, turn the cock back to "Prime or Water" position and insert the pick-up tube in another filled container. Turn the cock back to the "Foam" position and the outfit is ready to go.

FOG SPRAY INSTALLATIONS

Fog spray installations are used aboard certain type Naval vessels—such as carriers, transports, and cargo ships—where there is great danger of gasoline fires.

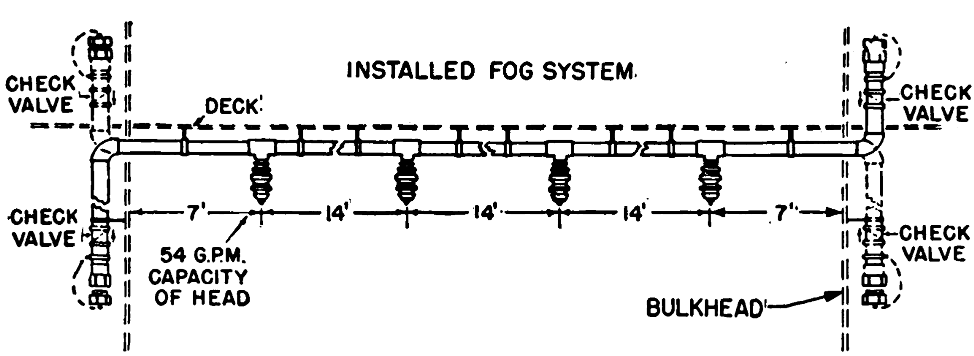

Figure 204.—Typical installed fog system.

As shown in figure 204, the installation is made up of overhead fixed piping, equipped with fog heads, which

are connected to either 1½ inch or 2½ inch swivel-type female hose connections. The connections are located on the opposite side of the compartment bulkhead—one connection on the same deck as the fog installation and one on the deck above.

For operation, the system is connected with 2½ inch hose to a convenient fire plug. The system is NOT AUTOMATIC.

CARBON DIOXIDE (CO_2) EXTINGUISHERS

Carbon dioxide extinguishers are used mainly in putting out electrical fires. However, they are also effective when used on burning fuel oil, gasoline, alcohol, and paint.

The PORTABLE EXTINGUISHER, which holds 15 pounds of CO_2 by weight, is shown in figure 205*A*. It has a disk-type release valve. To operate this kind of device, you carry it by the handle, pull out the locking pin, and turn the valve wheel. Other 15-pound portable extinguishers have a squeeze-grip type release valve, shown in figure 205*B*. With this type, you release the carbon dioxide by squeezing the release lever. Once this cylinder has been opened, it must be recharged.

NEVER PUT A USED EXTINGUISHER BACK IN ITS STOWAGE RACK. Fifty-pound commercial bottles of CO_2 are carried aboard ship by the supply officer for recharging the 15-pound extinguishers. These extinguishers must be weighed weekly, and when the weight drops to 13½ pounds (10% loss) they must be recharged. However, portable extinguishers stowed in hot locations such as engine rooms and open boats are given an initial charge of only 13½ pounds to allow for extra expansion at the higher temperatures.

A larger size extinguisher, which holds 50 pounds, is used for permanent installations. In both types, the CO_2 is held under a pressure of 850 psi at 70°F. When CO_2 is released from the container, it expands rapidly to 450 times its stored volume. Because it is 50 percent heavier than air, CO_2 flows downward, covers the fire, and excludes air until the fire is smothered. If there is wind or draft, try to work so that the carbon dioxide will be blown or sucked over the fire, not away from it.

Large cylinders containing 50 pounds of carbon dioxide are installed on larger ships. These cylinders are con-

nected to a manifold and used with a hose or with a piping system. Operation may be by LOCAL CONTROL, NOZZLE CONTROL, or REMOTE CONTROL. The remote control system causes a pin to pierce a disk which releases the CO_2. In this system, as in the 15-pound extinguishers, the cylinder cannot be turned off until its contents are exhausted.

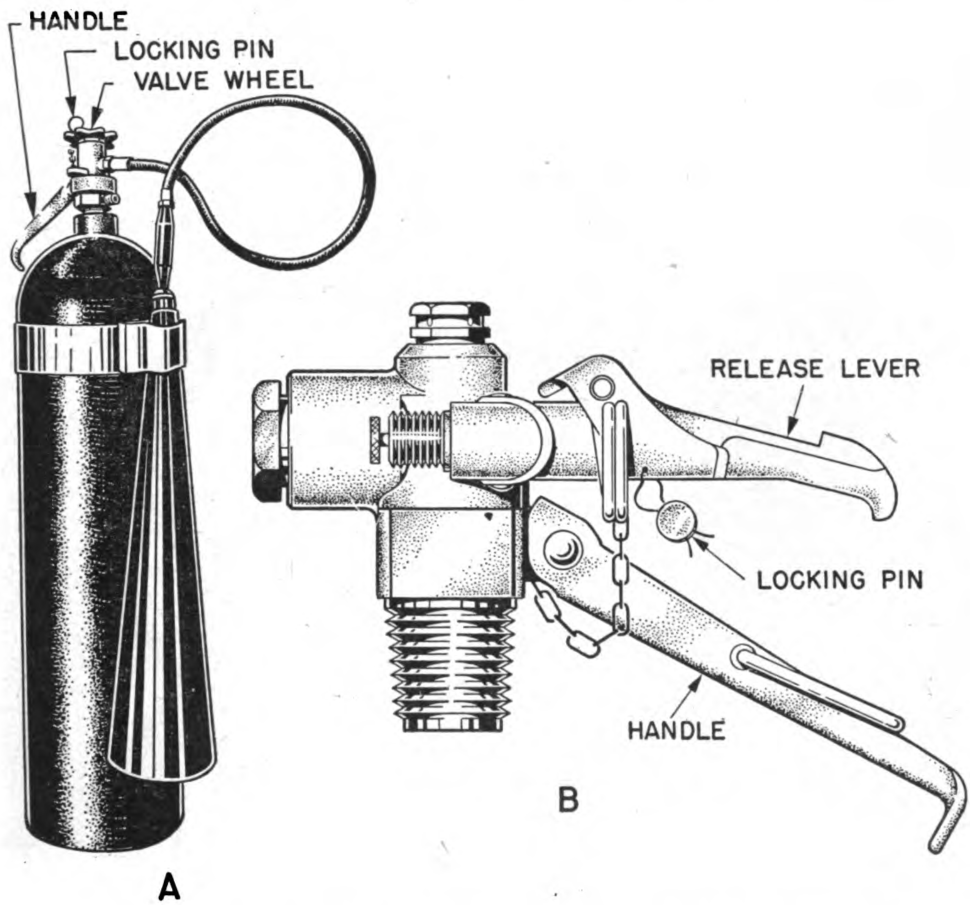

Figure 205.—*A*. Portable CO_2 extinguisher with disk-type release valve. *B*. Squeeze-grip type release valve.

The 50-pound extinguishers must be weighed quarterly, and replaced with a full cylinder if the weight has dropped to 45 pounds or lower.

When you are using CO_2 KEEP THE COMPARTMENT CLOSED.

CO_2 IS DEADLY! Don't use it unless you KNOW what you are doing. Don't enter a CO_2-flooded compartment until the compartment has been aired for 10 minutes or until a safety lamp, lowered into the compartment, burns

without interruption. However, a CO_2-flooded compartment may be entered in an emergency if you use an approved Navy rescue breathing apparatus or hose (air-line) mask.

THE HANDY BILLY

The handy billy (figure 206) is a portable water pump which is powered with a 2-cylinder, 2-cycle gasoline engine.

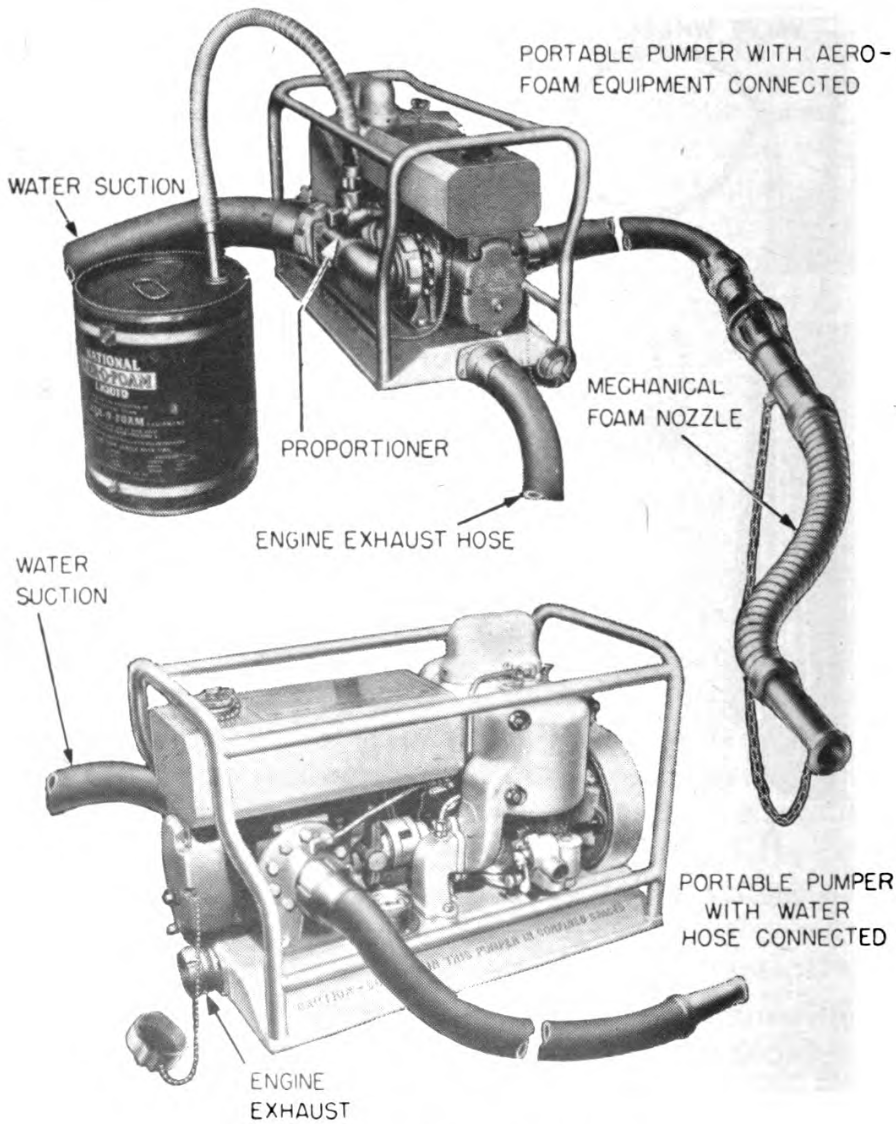

Figure 206.—The handy billy in two uses.

gine. The whole outfit weighs about 100 pounds. It will deliver 60 gallons of water per minute with 100 pounds of pressure. It may be used—

To throw water directly on a fire.

With a mechanical foam nozzle.

To increase hose pressure (when connected between two lengths of hose).

The combustion of the engine forms DEADLY CARBON-MONOXIDE GAS. The handy billy should be located where there is plenty of ventilation. If this is impossible, provide a safe exhaust extension. The exhaust hose should not be led more than 30 inches above the engine, or a back pressure will build up from an accumulation of water in the hose and will stop the engine. It is possible, however, to install a pet cock in the exhaust line to drain

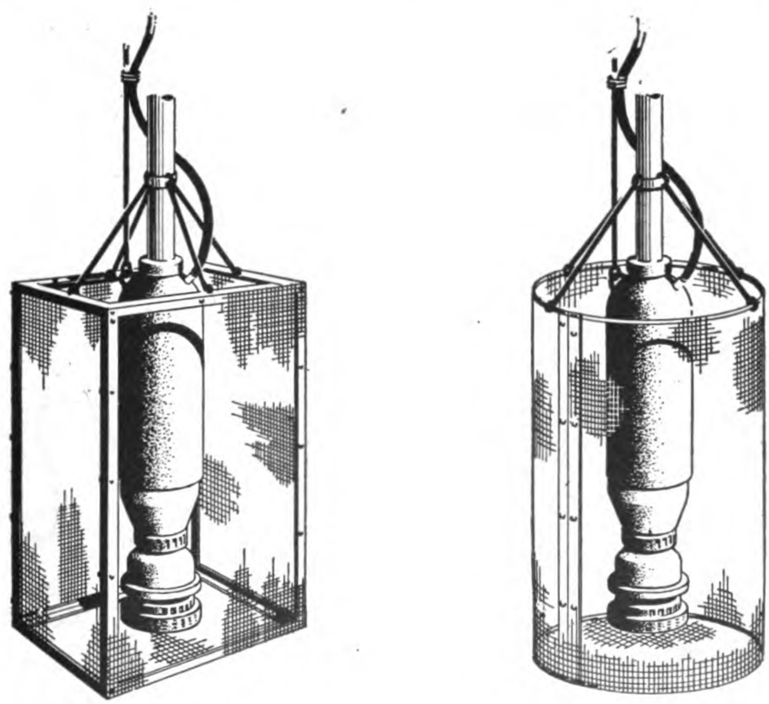

Figure 207.—Portable electric submersible pumps with basket strainers.

off water and prevent its accumulation. Or you can disconnect and plug the water connection to the exhaust manifold and allow the water to run on the engine bed.

ELECTRIC SUBMERSIBLE PUMP

The portable electric submersible pump (figure 207) is used for a wide variety of emergency purposes—to remove water from flooded compartments, to fight fires, to

circulate water through Diesel engines, and to operate eductors. If the strainer is clean and the discharge head is kept low, this pump can move 180 gallons of water per minute.

The efficiency of the pump is improved if a BASKET STRAINER is used in addition to the standard suction

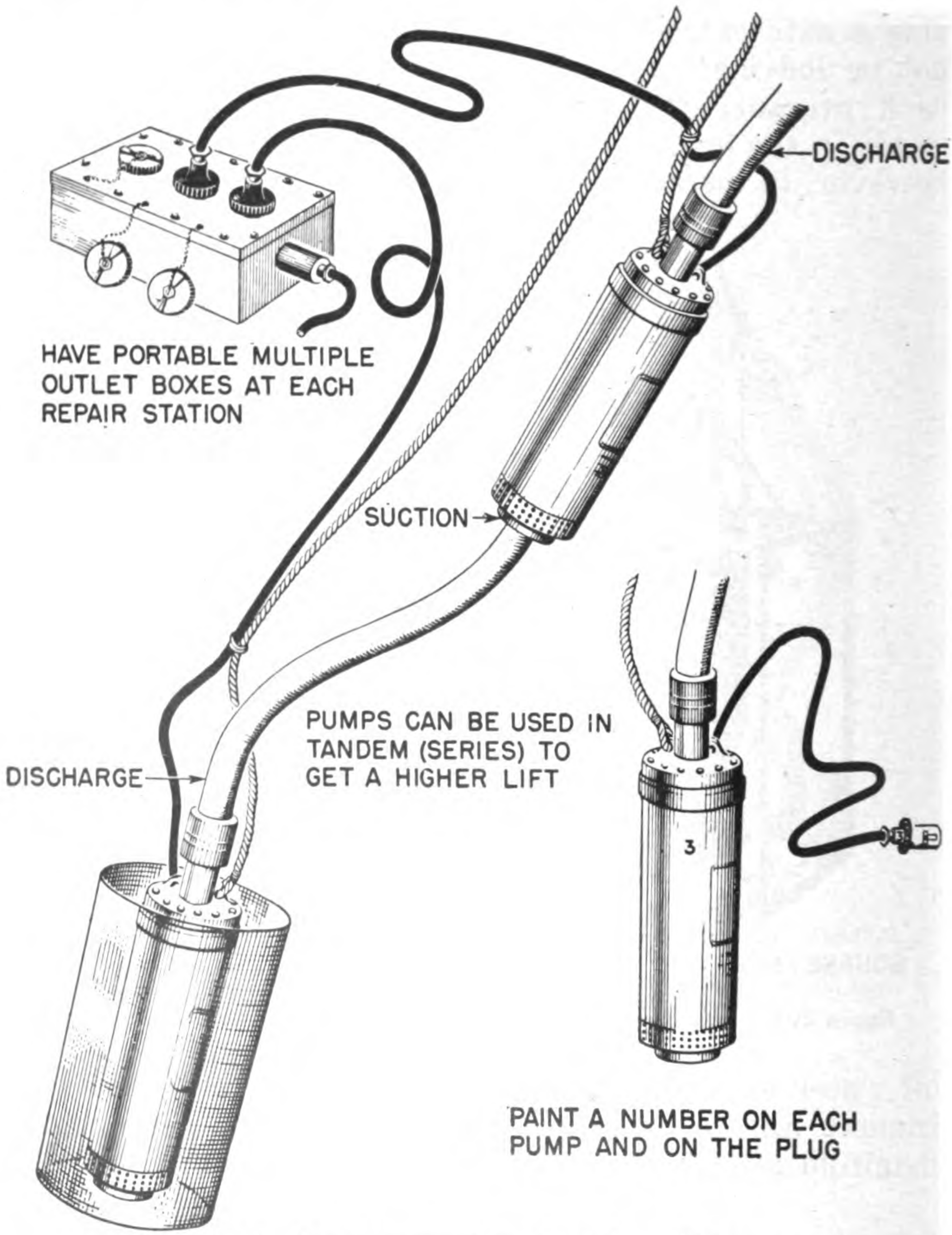

Figure 208.—Tandem connections for submersible pumps.

strainer that comes with the pump. Two types of basket strainers are shown in figure 207. You can make up these

baskets of No. 3 mesh (0.054″ wire) screen stock, which is available under the Navy Specification No. 42–C–21596. Baskets MUST BE used with the handy billy and P–500 when flood water is being pumped.

Submersible pumps should be lowered, raised and secured (while pumping) ONLY BY THE HANDLING LINE. This line, as you can see in figures 207 and 208, is secured to the pump housing through an eye for that purpose. NEVER RAISE OR LOWER THE PUMP BY THE ELECTRIC CABLE. This will break the watertight seal where the cable enters the housing. The handling line may be married to the power cable, providing considerable slack is left in the cable. (See figure 208).

To secure a higher lift, two submersible pumps may be connected in tandem, as shown in figure 208. A MULTIPLE-OUTLET BOX is provided (or should be constructed on board ship) for making the necessary electrical connections.

Use the following questions as a routine check list for your submersible pump—

Is the handling line properly secured to the eye of the pump?

Is the motor casing watertight? (Test with air pressure beforehand. Don't wait until you need the pump in an emergency.)

Are foot valves equipped with washers or gaskets?

Is a strainer mounted on the pump?

Is a spare strainer kept at each repair station?

Is the discharge fitting cap in place?

Is the cable stuffing tube properly packed?

Is a double-female adapter provided with each pump?

Is a portable multiple-outlet box provided at each repair station?

Is a 75′ jumper cable available for use in case of local power failure?

Are the necessary wrenches provided for removing and replacing strainers and for making hose connections?

SUBMERSIBLE PUMP SAFETY PRECAUTIONS

Keep in mind the following precautions when the pump is being placed in operation or is in actual use—

Be sure the pump is grounded to the ship's structure (not resting on non-conducting material).

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Keep handling line, electric cable and discharge hose CLEAR so that the pump can be removed quickly.
For maximum output, keep all hoses free of kinks.
Use strainer if at all possible.
Keep suction lift and discharge head as low as possible.
While the motor is operating, keep the suction end of the pump IN THE WATER.

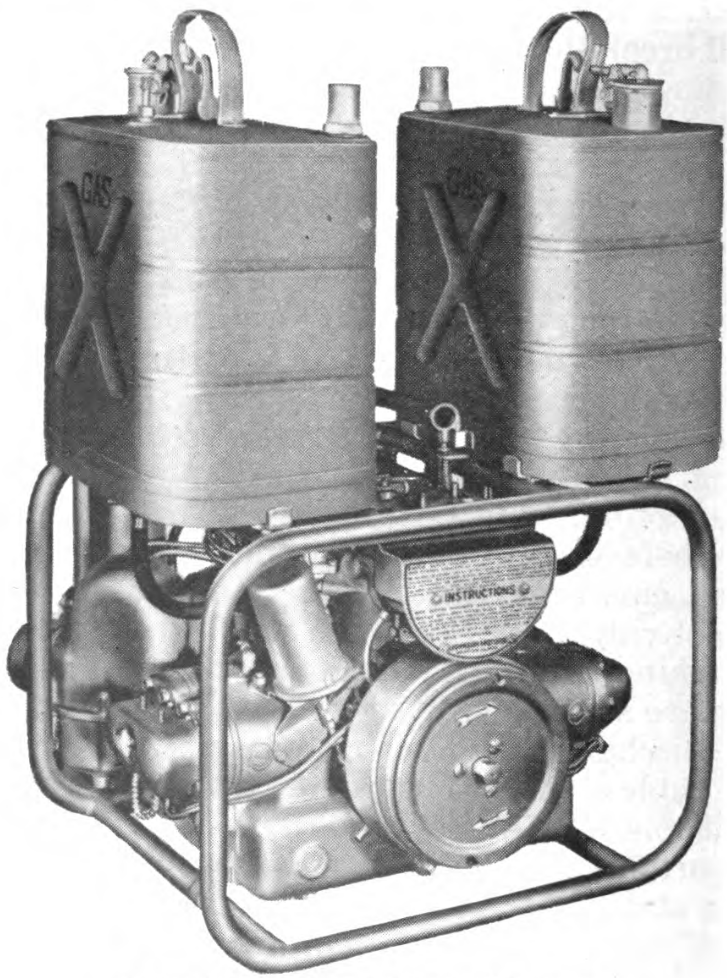

Figure 209.—The P-500 portable pump.

Keep the strainer clean at all times, using a wire brush.

And, above all, IF GASOLINE FUMES ARE PRESENT, NEVER USE AN ELECTRIC SUBMERSIBLE PUMP or any other apparatus that might produce a spark.

P-500 PORTABLE PUMP

The P–500 portable centrifugal type water pump is driven by a compact two-cycle, four-cylinder, water-cooled

gasoline engine of special design (figure 209). This pump is intended primarily to supply water for fighting fires, but it can be used for such jobs as removing water from flooded compartments and bilges.

This pump delivers 500 gallons of water per minute at 100 psi with a suction lift of 16 feet. With an eductor, the lift may be increased to 50 feet or more, but the water delivery drops proportionately.

Using a standard all-purpose 1½″ nozzle, the P–500 pump can supply six 1½″ hoses with a pressure of 100 psi. A pressure of only 75 psi can be maintained when two 2½″ hoses are used. With an eductor in use, the pump will maintain 100 psi in either ONE 2½″ hose or THREE 1½″ hoses.

Suitable means must be provided to carry the poisonous exhaust gases into the clear, particularly when the pump is used below decks. A standard 2½″ rubber suction hose is coupled to the exhaust outlet to remove the gases.

The speed of the engine and the water delivery pressure are controlled by a special PRESSURE REGULATOR which can be set for 75 to 140 psi. This regulator is usually set for 100 psi. When the pump loses prime, the regulator cuts the engine to idling speed to prevent overheating.

Before the pump is placed in operation, it must be PRIMED with water. One method of priming is to use a hand-operated vacuum pump to draw air from the pump body and suction hose, causing these spaces to be filled with water. In the other method, "bucket priming," you fill the pump body and suction hose through a cap opening on the top of the pump housing. To use the second method, you must have a tight foot-valve on the lower end of the suction hose to prevent escape of the priming water.

You may be called upon to operate the P–500 pump and to overhaul it. The manufacturer supplies a complete instruction manual with each pump.

STEAM SMOTHERING

Fires can be put out with steam. The steam smothers the fire in much the same manner as does fog. However, STEAM IS GENERALLY USED ONLY AS A LAST RESORT—when other methods fail. The use of steam carries the danger of injury to personnel or damage to equipment.

Usually, steam smothering installations consist of a line leading from an auxiliary steam line to engineering spaces. This line is so located as to distribute the steam effectively over as wide an area as possible.

KEEP YOUR SHIRT ON

Burn scars won't look good on you—and there's an easy way for you to help prevent them. Bare skin is cooked INSTANTLY by the flash from an explosion. All of that old strip-to-the waist, show-off-your-muscles stuff

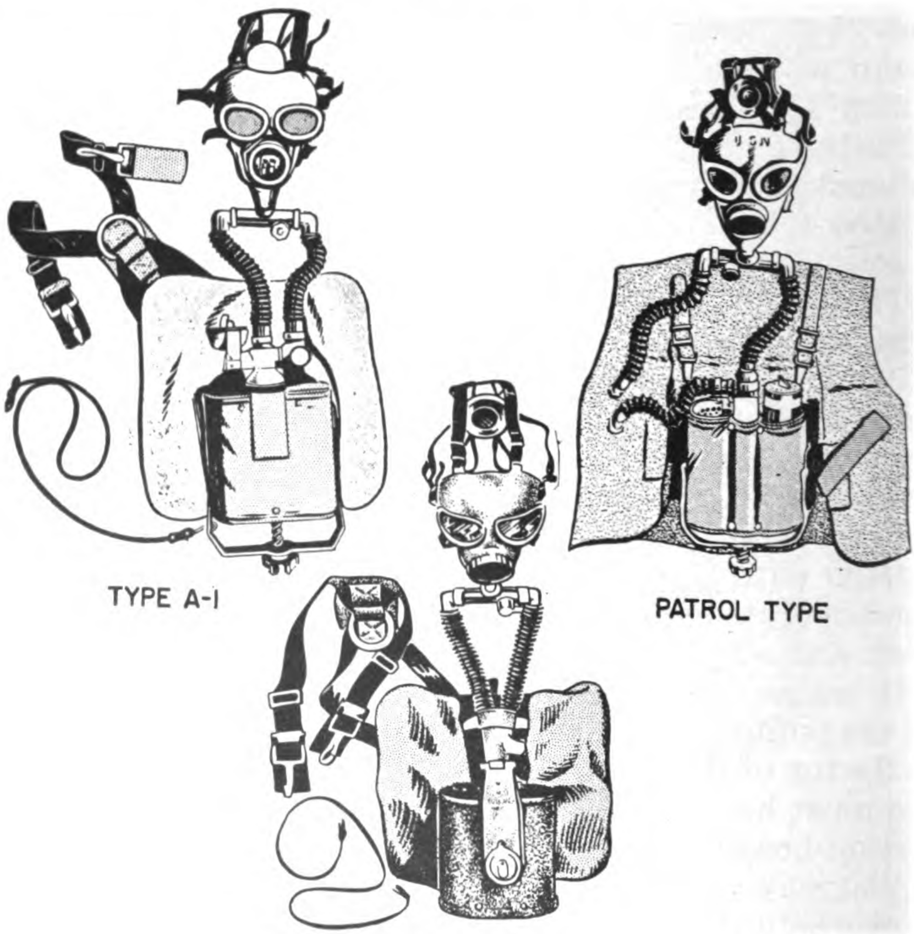

Figure 210.—Navy oxygen breathing apparatus.

is OUT when there is possibility of a fire or explosion. Any clothing which covers your skin, even a skivvie shirt, protects your skin. So—even when it's 120° in the shade—KEEP FULLY CLOTHED. Cover as much of the body as possible.

And don't forget to PROTECT YOUR EYES. Wear anti-flash goggles. Have them ready so you can slip them on when the alert sounds. It seems like a lot of trouble but it'll be a lot more trouble to have to feel your way down Main Street by tapping your cane on the sidewalk.

SPECIAL PROTECTIVE EQUIPMENT

The Navy believes in protecting its fire fighters. This protection includes the use of—

- OXYGEN BREATHING APPARATUS (four types).
- HOSE (AIR-LINE) MASK.
- ASBESTOS SUITS.
- LIFE LINES (steel-wire).

The four types of NAVY OXYGEN BREATHING APPARATUS—enabling the wearer to work safely in a gas-filled compartment—are called type A, type A–1, patrol type and oxygen-bottle type. Each of these devices is SELF-CONTAINED—a "closed circuit" in which oxygen is either "generated" or supplied for breathing. When the oxygen is generated, the equipment MAKES the air you breathe. So long as your breathing apparatus is working, you don't need any outside air.

Each breathing unit must have—

- An oxygen supply (chemicals or bottle).
- Means for cooling exhaled air (cooler in the bottle type; radiation from breathing bag and tubes in others).
- Storage space for "re-conditioned" air (breathing bag).

Type A, type A–1, and the patrol type apparatus (figure 210) have a special canister which contains chemicals. These chemicals absorb the CO_2 and water vapor from the exhaled air. The chemical reaction provides a supply of new air.

To change the A–1 and patrol type canisters, you have to come out into safe air. With type A, you can change canisters while remaining in toxic (poisonous) air.

In the bottle type apparatus (figure 211) the air is purified by a chemical—but this chemical does not "generate" new oxygen. In this device, the oxygen content of the air is maintained by automatically-controlled, or hand-controlled, additions from the small oxygen bottle.

It isn't necessary to give here the step-by-step instructions on how to use the different types of breathing apparatus. The operation has been demonstrated to you—or if it hasn't, it will be. Mostly it's just a matter of knowing how to put the thing on, how to insert a canister, and when to turn the timer dial, hand wheel, or working

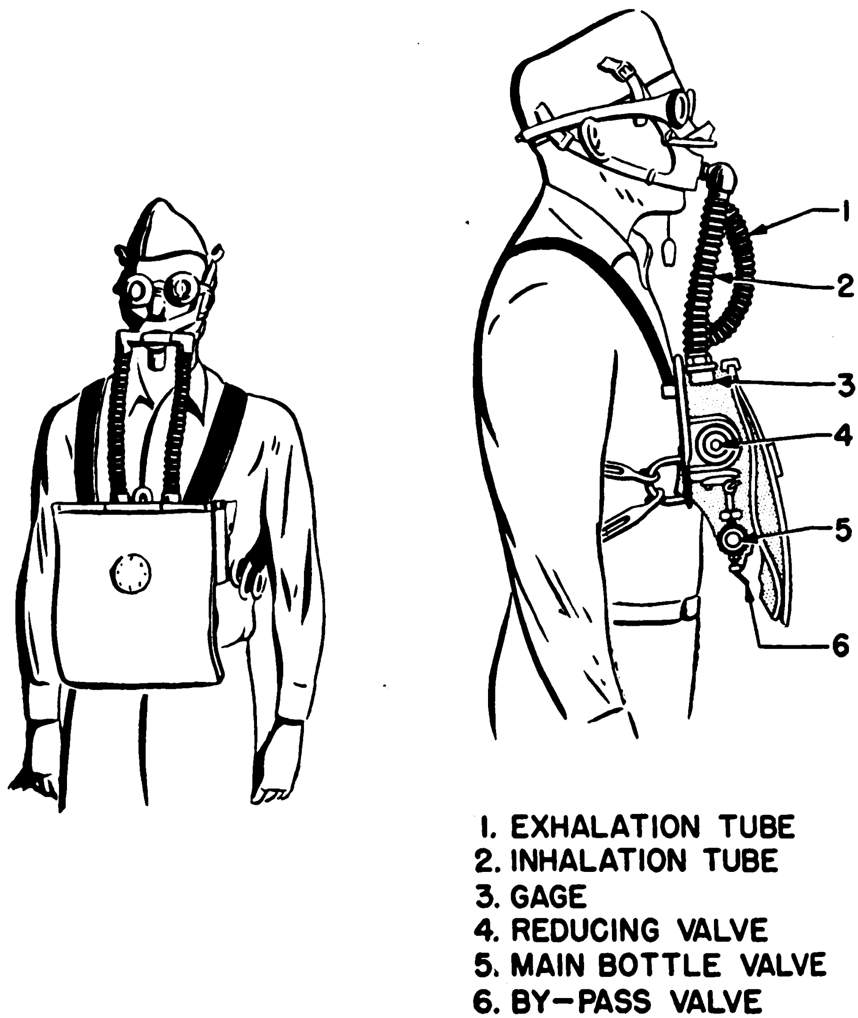

Figure 211.—Navy oxygen breathing apparatus. Oxygen bottle type.

valve. If you need to brush up on the details, get someone who knows to show you, using actual apparatus.

HOSE (AIR-LINE) MASK

The Navy has authorized the use of a hose mask for fire fighting and damage control work, and this apparatus is now standard stock. It is highly effective, and can be

constructed easily from the face piece and breathing tubes of a regular Mark 3 or Mark 4 Navy type gas mask. The hose mask provides breathing and eye protection in

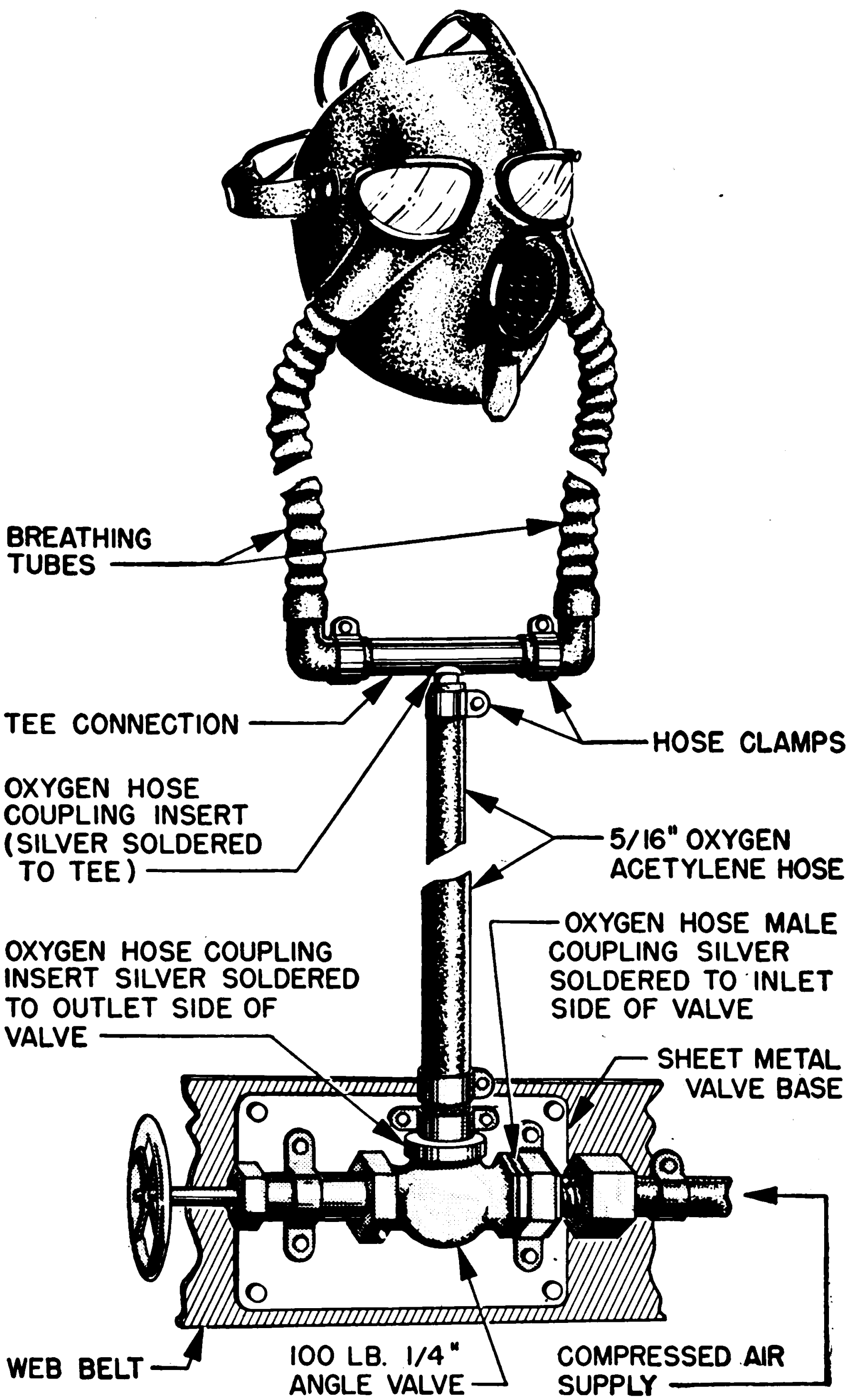

Figure 212.—Assembly of the hose (air-line) mask.

spaces contaminated by any type of gas or vapor, and in a space where there is a lack of oxygen. All that is needed is an air-line hose which will give a continuous supply of pure air to the facepiece at a pressure slightly above the surrounding pressure.

To give you a clear picture of the construction of the hose mask, study the following directions for converting a gas mask into a hose mask (refer to figure 212)—

Remove the gas mask canister.

Connect the ends of the two corrugated rubber tubes to a tee fitting.

Secure a low pressure angle valve to a strong web ammunition belt.

Connect the outlet side of the angle valve to the inlet side of the tee fitting with a short length of oxygen hose.

Install threaded unions on the ends of the air supply hose.

Connect the outlet side of the angle valve to the inlet side of the tee fitting with a short length of oxygen hose.

Install threaded unions on the ends of the air supply hose.

Connect the air supply hose to the angle valve.

The following materials are needed to convert a Mark 3 or Mark 4 gas mask into a hose mask. The materials are listed with stock numbers taken from the standard stock catalogue, and requisition forms should be made out exactly as this list is worded.

The hose (air-line) mask will be found useful on frequent occasions where the conditions make it difficult to use the bulkier oxygen rescue breathing apparatus. It should be part of every well-equipped repair party locker. One length of air hose (and of tender-line) should be attached to the mask at all times, kept neatly coiled and ready for instant connection to any of the available sources of air supply.

The most common source of air supply is the low-pressure ship's service line. It is advisable to run this air through an air filter before it enters the mask. The full pressure of the low-pressure line can be admitted to the control valve, and the wearer can regulate the flow to

suit his needs. YOU CANNOT GET TOO MUCH AIR INTO THE MASK. All excess air escapes around the face mask. Air can also be taken from an air flask, and you can use an oxygen bottle if the proper adapter fittings are on hand.

TENDING THE LINES

The air line and safety (life) line of the hose mask, and the safety line on any man wearing rescue breathing apparatus, must be closely tended at all times by a competent

ITEM	STANDARD STOCK #	ARTICLE	AMOUNT NEEDED
1	33–H–453	Hose, Gas, Oxygen — Air (Black Cover) 5/16″ I.D., 50 ft. lengths.	1–No.
2	33–C–530	Couplings, Oxygen, Hose, 9/16″ National Standard R.H. thread composition.	4–No.
3	45–V–4351	Valve, composition, 100 lbs. working pressure, angle.	1–No.
4	21–C–224	Cord, Sash, cotton braided, Type A #8, 50 ft. lengths.	1–No.
5	On Board	Belt, web, rifle, ammunition..........	1–No.
6	33–C–87	Clamp, Hose, diameter (open) 1 3/16″.	2–No.
7	33–C–72	Clamps, Oxy–Acetylene Hose, Bolt-Pattern Brass 3/8″.	4–No.
8	On Board	Brass tubing 1″ O.D. 4″ long.........	1–No.
9	45–C–5020–300	Couplings, Male, 9/16″, oxygen hose connection.	1–No.

man. The purpose of this is to see that the lines do not become fouled or cut by jagged edges. And it is necessary that the wearer and tender be able to communicate with each other by means of signals, the standard signals being the diver's signals.

ASBESTOS SUIT

Asbestos will not burn, but it does conduct heat. An asbestos suit, therefore, gives protection against flames for ONLY a short time. It does, however, allow you to move quickly through flame to effect a rescue or do some other job that can be accomplished rapidly. The suit can be used with rescue breathing apparatus WORN OUTSIDE, as shown in figure 213. The wearer should be completely clothed before putting on the asbestos suit.

When a man is wearing an asbestos suit, it is seldom advisable to spray him with water while he is working on a fire, because the suit would become water-soaked and heavy. If, however, you are directed to use that procedure, DO NOT STOP THE STREAM OF WATER UNTIL THE MAN IS CLEAR OF THE FIRE AND THE SUIT HAS COOLED. If

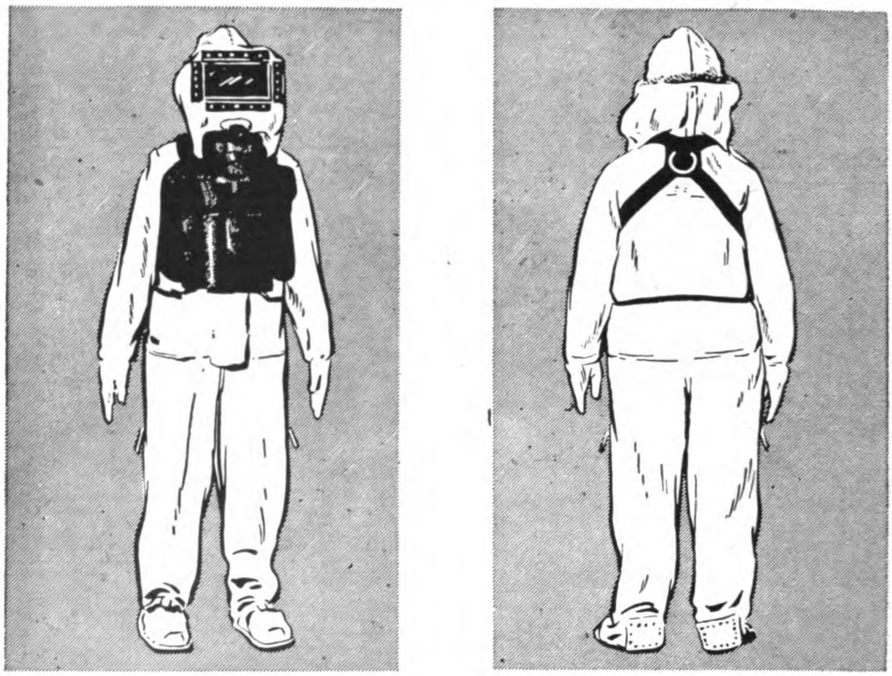

Figure 213.—Asbestos suit with rescue breathing apparatus.

you stop the water after the suit is once wet and while the suit is still hot, the water will turn to steam and scald the man. In normal practice, water is NOT played on the man while he is fighting the fire. In that case, DO NOT SPRAY HIM WHEN HE COMES OUT OF THE FIRE. The hot suit would cause the water to flash into steam, and burn the man.

LIFE LINE

The Navy provides the type of life line shown in figure 214. It is a 50 foot length of woven steel-wire cable with snap hooks at each end. Notice, in figure 213, the BACK LOOP on the asbestos suit harness to which the life line may be secured. Work in pairs.

The life line should be attached to the UPPER PART of the body, preferably to the back of a shoulder harness.

A cardinal rule is: NEVER ATTACH A LIFE LINE TO THE WAIST. If the line were pulled, it might interfere with the stricken man's breathing or injure him internally. Furthermore, when a man is being hauled up or dragged out, it is best that he be pulled toward you head first. That gives the rescuer better control and there is less danger

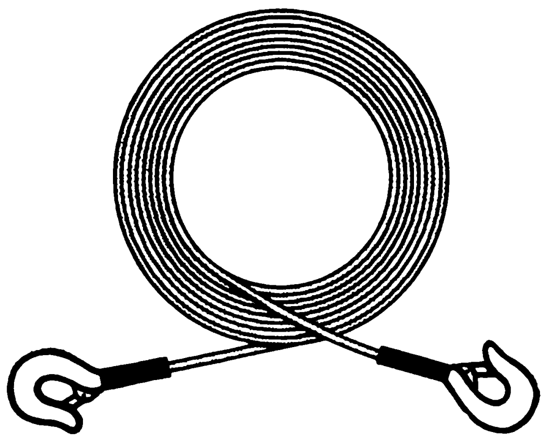

Figure 214.—Fire fighter's life line.

that the man's body will jam crosswise in a door or against some other obstruction.

KEEP FULLY INFORMED

Most of the material in this chapter on the methods and equipment used in combatting fires aboard ship is based on the FIRE-FIGHTING MANUAL (NavShips 668). Read that book and other books on fire fighting and damage control that are available to you. Remarkable advances have been made recently in fire fighting and more will be made—keep up with them.

CHAPTER 16

DAMAGE CONTROL

KEEPING THE SHIP AFLOAT

Every man aboard a ship is interested in keeping her afloat and under way. You may be a member of a damage control repair party, and perhaps in charge of the party. This is a serious matter, and you'd better learn your damage control duties thoroughly.

DAMAGE CONTROL means doing anything that can be done to—

Preserve the watertight integrity of the ship.

Maintain the stability and maneuverability of the ship.

Make rapid repairs to damaged gear and structures.

Furnish fire protection and extinguish fires.

In other words, DAMAGE CONTROL IS ANY PROCEDURE WHICH HELPS TO REDUCE THE HARMFUL EFFECTS OF ANY DAMAGE TO THE SHIP.

KNOW YOUR SHIP

Learn all you can about YOUR SHIP—THE WHOLE SHIP, not just the part to which you are assigned. In an emergency you may have to work anywhere on the ship, depending on the location and extent of damage.

Be able to find your way to any compartment in the dark, and be able to close any valves, doors or hatches by FEEL ALONE. If you can do that you will be an effective man in any repair party.

Know the important DAMAGE CONTROL SYSTEMS—

Drainage and flooding.
Fire main and sprinkling.
Ventilation.
Fuel and fresh water.
Compressed air.
Communication.

In addition to knowing these systems, KNOW YOUR OWN ASSIGNED JOB PERFECTLY. You can get information on these systems from your ship's DAMAGE CONTROL BOOK, DAMAGE CONTROL BILL and CASUALTY CONTROL BILL. You will learn a lot from drills and practical experience. Danger may appear at any time—BE PREPARED.

Now take a look at the damage control systems.

DRAINAGE AND FLOODING SYSTEM

The purposes of the draining and flooding equipment are—

Removing large amounts of water from compartments and spaces after battle or other damage.

Removing water from the hull under normal operating conditions.

Flooding compartments to balance the ship.

There are three principal types of fixed mechanical drainage systems—MAIN DRAINAGE, SECONDARY DRAINAGE, and MAIN CONDENSER CIRCULATING PUMPS.

The MAIN DRAINAGE SYSTEM has a high capacity, and is made up of piping and pumps that can move large quantities of water in a short time. This is necessary in draining large spaces such as the engine and fire rooms. The piping is either a fore-and-aft line or a loop around the room. Smaller branches and take-offs reach bilge wells, tanks and other compartments. Learn the valves and how to operate them.

The SECONDARY DRAINAGE SYSTEM serves to drain the small compartments forward and aft of the main damage system. The capacity of this system is small compared with that of the main drain. It usually consists of one fore-and-aft line, with branches to the compartments.

The secondary drainage of destroyers and smaller ships is usually accomplished by submersible electric pumps.

The MAIN CONDENSER CIRCULATING PUMPS can be used for emergency drainage of the engine rooms. These are large capacity pumps (usually centrifugal), whose normal job is to circulate water from the sea to the main condenser in the engine or machinery rooms and discharge it overboard again. However, each pump has a secondary bilge suction from the engine room in which it is located, and the pump can drain this space in an emergency. No other space can be drained by this type of pump unless, by accident or design, another space should drain into the engine room where the pump is located.

Sometimes compartments are intentionally flooded to improve the balance of the ship. Flood compartments only when ordered to do so by the proper authority. Your job may be to open and close the necessary valves. Be sure you operate the right valves and controls.

In addition to the three fixed mechanical drainage systems, there is a system of drainage by gravity and also various items of portable equipment for drainage. Spaces above the waterline (deck drains in compartments, wash rooms, pantries, galleys and heads) are drained overboard by gravity. In some exceptional cases, spaces at or near the waterline drain by gravity into a bilge well or other lower space, from which water may be pumped overboard by the main or secondary drainage system. The main types of portable equipment for drainage are—portable submersible pumps, handy billy pumps, portable jet pumps (eductors) and hand pumps.

FIRE MAINS AND SPRINKLING SYSTEMS

The fire main system is made up of piping, pumps, plugs, valves and controls. The system is designed to supply PLENTY of water for fire fighting, sprinkling the magazines, washing the decks, and any other purpose for which salt water is normally used.

The piping may be a straight line or there may be a loop system on larger ships. Risers go from the fire main to fire plugs on the upper deck levels. The fire main system is so designed that any damaged section of piping can be cut out of the system. That's why there are so many

CROSS-CONNECTIONS and SHUT-OFF VALVES all through the piping.

VENTILATION SYSTEMS

The ventilation systems aboard a ship SUPPLY FRESH AIR and REMOVE STALE AIR AND GASES. Ships have sufficient blowers to force fresh air through all compartments and through spaces below the waterline that are designed for ventilation.

The ventilation system helps to PREVENT FIRES AND EXPLOSIONS by preventing the accumulation of explosive gases.

FUEL AND FRESH WATER SYSTEMS

Fuel and fresh water systems consist of tanks, filling lines and feed lines. These are important in damage control because the LIST and TRIM of the ship can be partially controlled by shifting the contents of the tanks. This method of balancing is better than flooding when the damage is below the waterline. Your ship's "oil king" works with the chief engineer (with the consent and advice of the Damage Control Officer) on damage control problems that involve the transfer of tank contents.

COMPRESSED AIR SYSTEM

Compressed air lines provide air for guns and torpedoes and for testing and blowing out compartments and tanks. Compressed air also powers pneumatic tools used in damage control and maintenance work.

COMMUNICATION SYSTEM

When a ship is in action, the communication system is of vital importance. Control stations must be notified as to—

Location of casualties.
Extent of damage.
Corrective measures taken.
Progress being made.

As a member of a DAMAGE CONTROL PARTY, you must familiarize yourself with the various means of communication—particularly with the SOUND-POWER telephone

system. Know where JACK BOXES are located and what systems and circuits they serve.

LEARN THE FOLLOWING CIRCUITS and the auxiliary circuits connected with them.

JZ—Communication between repair parties.

JA—Captain's battle circuit for intercommunication between damage control and conn.

JV—Ship control circuits for intercommunication between damage control and such ship control stations as conn, battle two, and steering engine room.

JL—Lookout circuits for intercommunication between damage control and lookout circuits.

SHIP COMPARTMENTATION

The effectiveness of damage control procedures is based on proper compartmentation of the ship. The ship is divided into compartments to—

Control flooding.

Restrict chemical agents and gases.

Segregate activities of personnel.

Provide underwater protection by means of tanks and voids.

Strengthen the structure of the ship.

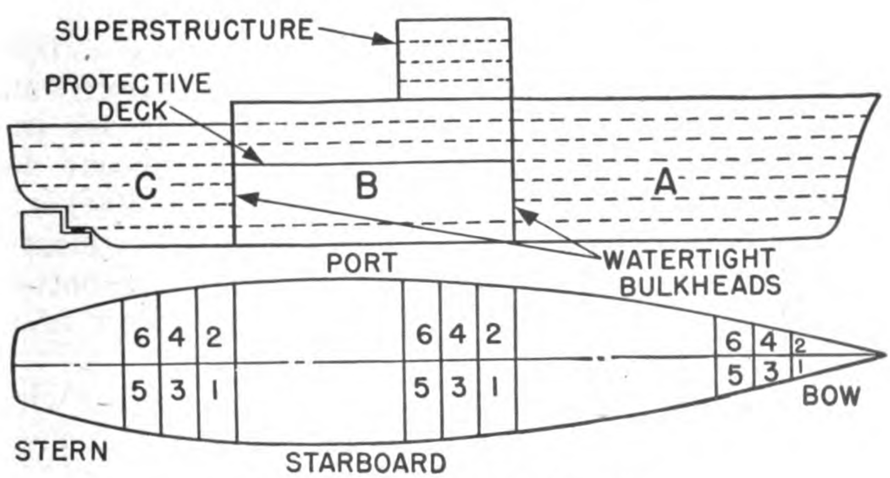

Figure 215.—Divisions of a ship.

Compartments are designated and identified by SYMBOLS which are made up of LETTERS and NUMBERS. Each compartment has its own symbol, which is stencilled on the bulkhead, hatch, or door. PORT compartments have

EVEN numbers. STARBOARD compartments carry ODD numbers.

The first letter of the symbol is always, A, B, C (and D in older ships). *A* indicates a compartment located FORWARD of the machinery space; *B* refers to AMIDSHIPS or machinery spaces; and *C* means the compartment is AFT of the machinery spaces. In older ships the B and C compartments are in the machinery spaces; D compartments are aft of the machinery spaces. The divisions of a new (three-division) ship are indicated in the upper diagram of figure 215. The lower diagram represents the way a new series of compartment numbers begins at the

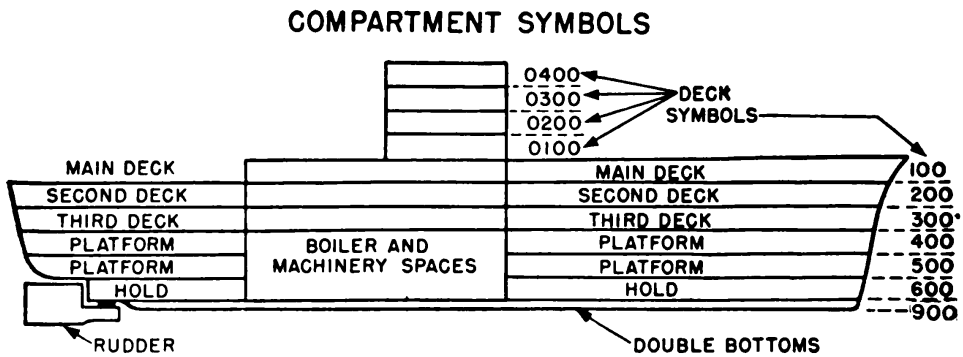

Figure 216.—Compartment-deck numbers.

forward end of each division, with the even numbers on the port side and the odd numbers starboard.

After the division letter, the deck designation comes next in the symbol. Main deck compartments are indicated by numbers such as 102, 109, or 117. Second deck compartments form a 200 series, third deck a 300 series, etc. A zero preceding the number indicates a location above the main deck. See figure 216. The double bottoms always form a 900 series on any ship regardless of the number of decks above.

The use of a compartment is indicated by a letter which FOLLOWS the symbol number. The letters and their meanings are—

A—supply and storage
C—control
E—machinery
F—fuel
L—living quarters
M—ammunition
T—trunks and passages
V—voids
W—water

Here's a sample of a compartment symbol.

```
C - 2 1 7 A -
| |  |  | |___supply compartment
| |  |___________compartment number (starboard side)
| |______________second deck
|________________after part of ship (C division)
```

Learn this standard compartment symbol system. It's used on all ships except a few of the older ones which have the additional sub-division D. When you are ordered to go to a designated compartment you must be able to get there with a minimum of confusion and delay. KNOW WHERE YOU ARE GOING.

DAMAGE CONTROL PARTIES

When a ship is commissioned, some of the crew members are immediately organized into damage control parties. The number of such parties depends on the size and type of the ship, damage control equipment and facilities provided, and the number of men available for assignment. A destroyer will probably have only three parties. A battleship usually has six, designated this way—

STATION DESIGNATION	LOCATION
Repair I	Main deck (and above) repair
Repair II	Forward repair
Repair III	After repair
Repair IV	Amidships repair
Repair V	Engineering repair
Repair VI	Ordnance repair

Aircraft carriers usually have two additional repair parties—Repair VII (gasoline stowage and repair) and Repair VIII (flight deck).

Each damage control party contains a number of DIFFERENT ratings. This provides skilled men for any type of work and insures against all the men of one rate being wiped out by a single hit. For example, if you are assigned to Repair 5, you'll find that this party also includes Machinist's Mates, Motor Machinist's Mates, Electrician's Mates, Water Tenders, Boilermakers and others.

GENERAL DRILLS

A well-organized and trained damage control party functions like clockwork because, when the signal is given, every man knows WHERE TO GO and WHAT TO DO. You'll get most of this training in the form of EMERGENCY DRILLS and damage control lectures, which prepare you for any casualty.

YOUR duty at YOUR station is an important cog in the operation and safety of the ship. The drills develop PRECISION TEAMWORK. You know that a basketball team does not develop a good zone defense or fast break without plenty of TEAM DRILL and PRACTICE. By the same token, the ship's crew cannot control casualties without extensive drill, practice and TEAMWORK.

The details of the emergency drills are given in *The Bluejacket's Manual* and other publications.

The most important of all drills is GENERAL QUARTERS. The general quarters call means that you move ON THE DOUBLE to your battle station without unnecessary noise and confusion. And don't forget the traffic rules on YOUR SHIP.

ROUTINE MAINTENANCE

Incorporated in the design of a ship are many small compartments, in which various mechanical features are installed to aid you in controlling damage. The watertight fittings, fire fighting equipment, and other systems are all there to keep the ship AFLOAT, UNDER CONTROL and FIGHTING.

As a Metalsmith, you'll be responsible for maintaining some of these installations. They must be kept in tip-top condition AT ALL TIMES. And it's YOUR job to know their locations, what their functions are, how to operate them, and how to repair them when necessary.

PREPARATION FOR ACTION

It is obvious that the ship's watertight integrity has much to do with damage control. When she is going into battle, or at any time when damage may be sustained, she must be as "tight" as possible. So proper PREPARATION of the ship for action is the most important part of damage control procedure.

Navy vessels maintain different MATERIAL CONDITIONS according to whether contact with the enemy is improbable, probable, or imminent. Each condition represents a different degree of tightness; the ship may be fairly well opened up when there is little danger of damage, but it will be closed up as much as possible when the danger is great and immediate. All doors, hatches, valves and other fittings of damage control value are classified and marked, and these designations tell what fittings must be closed for each material condition.

Battleships, large carriers, and heavy cruisers have THREE material conditions—X-ray, Yoke, and Zebra; smaller ships may have two—Able and Baker. Here's the material condition picture in table form—

CONDITION		DAMAGE IS	CLOSE FITTINGS MARKED
Largest Ships	Smaller Ships		
X-RAY		Improbable	X
YOKE	BAKER	Probable	X and Y
ZEBRA	ABLE	Imminent	X, Y and Z

Some doors, hatches and valves MUST BE LEFT OPEN during battle, and they are designated W (William).

DAMAGE REPAIR

If each member of the crew knows his stuff, emergency repairs can be accomplished in a hurry and without confusion.

REPAIRS IN ACTION are strictly EMERGENCY. You'll have to use whatever material is at hand. Plug holes with anything that you can lay your hands on. THINK AND IMPROVISE. Remember—the important thing is to KEEP THE SHIP AFLOAT.

Battle damage you'll have to worry about includes hull ruptures, punctured bulkheads, flooded machinery spaces, warped doors, ruptured decks, leaking piping, damaged machinery, weakened structures, and wreckage which interferes with the ship's functions.

HOLES IN THE HULL

Small holes in the underwater hull result from near miss bombs or violent explosions in other parts of the ship.

Temporary repairs can be made by driving WOODEN PLUGS or wedges into small holes. Use bare, soft wood because it soaks up water, swells, and holds the plug or wedge firmly in place. PAINTED wood will not do this.

If you wrap the plugs with cloth you'll get an additional seal. Oakum may be driven into the blank spaces between the plugs. SQUARE-END plugs hold better than conical shaped plugs.

Wedges should NOT be driven into cracks because they will cause the cracks to enlarge and expand. Before you try to fill a crack, drill a small hole at each end of the crack. Plug these holes with wood or with machine screws. Then lay a flat piece of rubber or canvas over the crack, back it up with a board, and hold the patch in place with shoring. This type of patch must be inspected frequently as it tends to shift and slip as the ship "works".

Large hull holes through which water is pouring are difficult to control. The only control may be to establish watertight boundaries in order to isolate the damage and confine it to as small an area as possible.

Hull holes ABOVE THE WATERLINE may be more dangerous than they look. When the ship rolls, these holes may admit water into spaces above the center of gravity and REDUCE THE STABILITY of the ship. Holes like this are given high priority. They are not difficult to patch. You can use either inside or outside patches on them. Inside patches may be made with pillows and mattresses, backed up with boards or mess table tops, and shored. (Shoring methods will be discussed a little later.)

A good outside patch can be made with a pillow or mattress which has a hole punched in the center. The back-up board must also have a hole in the center. A stout line is passed through the padding and board and knotted securely behind the board. The entire patch is then placed on the outside of the hole. The line is passed through the hole and secured to a stanchion on the inside. The line can be tightened with a Spanish windlass.

MORE PATCHES

A special prefabricated "folding-T" patch has been developed for use over relatively small holes. The stock of the "T" is threaded and fitted with a washer and nut. A

board and a pillow, each with a hole in the center, slide over the stock. The assembly can be folded, pushed through the hole, and tightened on the inside.

A simple type of patch you can make for large holes is just a steel plate with a hole drilled through the center. A knotted rope is passed through the hole and used to secure the patch when it is installed. A padeye with a long handling line should be installed on the edge of the patch for lowering it on the outside of the hull. The handling line is also used to support the patch after installation. The patch is sealed with a rubber gasket. One vessel reported that it returned to base with 84 of these patches in place. Sizes up to 5′ diameter have been used with success.

Another patch, especially suitable for holes with jagged edges sticking inboard, is a miniature COFFERDAM or open box. It may be made of either wood or metal. The wooden version is usually 18″ square and 6″ deep. It can be shaped to fit the contour of the hull, fitted with a rubber gasket, placed over the hole, and shored in place. The steel boxes are welded with angle clips.

MINOR LEAKS

As a result of bomb or collision shock, or structural distortion, a variety of small leaks may appear. These occur around stuffing tubes, piping, and loose rivets, and where angle irons have been pulled from decks and bulkheads. Many leaks of this kind can be repaired permanently as soon as they are reported.

Some minor leaks can be stopped by driving lead slugs, wires, strips, or plugs into them. Plugs cut from sheet lead are effective in stopping leaks where plate has been pulled loose where it's riveted. Avoid welding a damaged riveted joint. The heat of welding may tend to spread the trouble to a larger area.

Rivets and bolts can be used to fill small holes if you have access to both sides of the bulkhead. Machine screws can be tapped into small holes which are accessible from only one side.

STRENGTH MEMBERS

Beams, frames, decks, and most bulkheads are strength members of the hull structures. If they give way or be-

come weakened, the hull may collapse or break in two. Small vessels may not have the necessary equipment for extensive repairs. Some help can be afforded by shifting weights and by shoring.

Larger ships will have suitable equipment and stores for making extensive repairs. In addition to shoring, beams and frames can be patched and strengthened by bolting and welding reinforcing bars and plates along the webs.

SHORING

SHORING consists of BRACING members (or patches) so they will withstand the necessary pressure. Standard

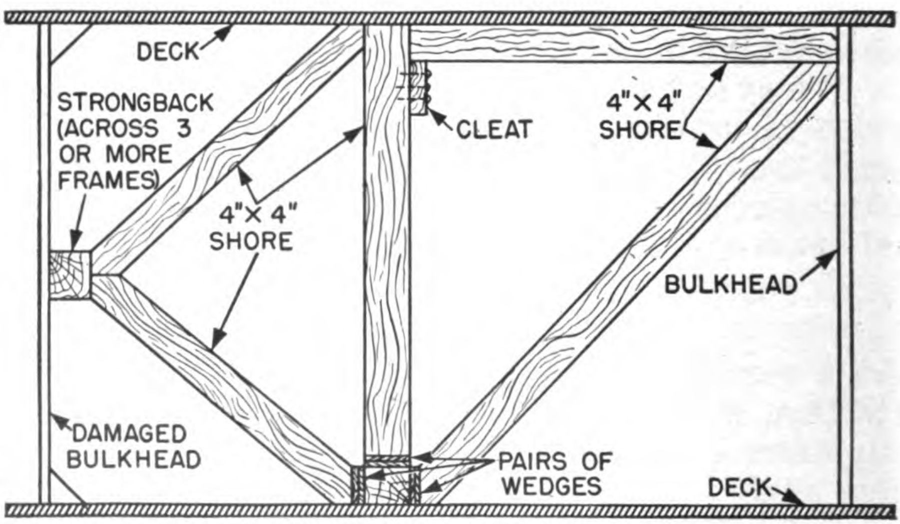

Figure 217.—One type of shoring.

methods of shoring are shown in figures 217 and 218. Most shoring is done with wooden 4″ × 4″ timbers. In emergency, such gear as mess tables, lengths of piping, and steel bars are used. Some ships carry adjustable, telescoping shores. Others have angle bar shores which can be tack-welded in place. Note in the illustrations how wedges are used to secure the bracing beams.

It's improbable that any two shoring jobs will ever be handled in the same manner. Common sense and good judgment are essential. Use the following principles as a guide—

Bulkhead should be shored to decks, to beams overhead, or against stanchions and hatch combings.

It's important to allow a three-point distribution of forces.

Exert every effort to avoid damage to flanges, bulkhead stiffeners, or deck beams. Too much pressure may cause damage to other bulkheads and decks.

Avoid breaking calked seals.

Use unpainted wedges and don't force them too much. If decks are oily, sprinkle dry sand under the wedges.

WRECKAGE REMOVAL

Wreckage that interferes with the FIGHTING EFFICIENCY of the ship must be cleared quickly. But hazards which may cause fire, flooding, or personnel injury must be removed before wreckage can be cleared. Switches must

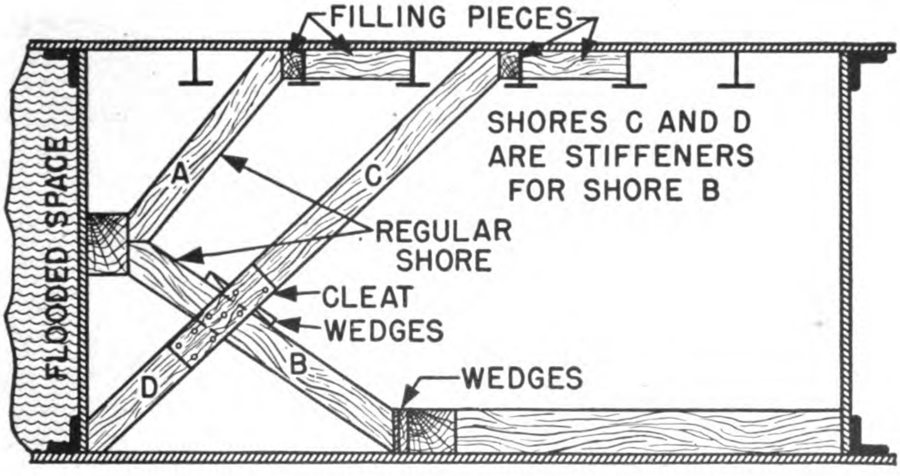

Figure 218.—Shoring to a distant bulkhead.

be opened and valves closed. The working atmosphere must be SAFE. Rescue breathing apparatus may be necessary. Before doing any work which might cause a spark of flame, check the air with an EXPLOSIMETER. It will tell you whether there is a dangerous concentration of explosive gases.

Loose wreckage can be removed by hand. Many pieces and objects will require cutting or breaking. Power chisels and acetylene cutting equipment are best for clearing extensive damage. When power is OUT, it may be necessary to use mauls, sledges, axes, heavy cold chisels, rivet bars, and pinch bars.

Sometimes it's necessary to remove burning bedding, stores, and supplies. For this work a "devil's claw" is handy. It is a rake with three steel claws and an eight-foot handle made of $\frac{3}{4}''$ steel pipe.

Fire extinguishers, hose, and rescue gear should be kept at hand when you are clearing wreckage. If you don't play safe **YOU MAY CAUSE ADDITIONAL DAMAGE** and **LOSS OF LIFE.**

How Well Do You Know the Duties of—

METALSMITH 3c AND 2c

QUIZ

CHAPTER 1

THE METALSMITH'S WORK

1. To what department and division is a Metalsmith ordinarily assigned?
2. Why is a Metalsmith usually assigned to a damage control party?

CHAPTER 2

SHEET METAL WORK

1. What is the thickness capacity of most squaring shears?
2. How is the amount of curve of a bend in sheet metal usually designated?
3. Which stake would you use to form the body of a funnel?
4. What important part of the cornice brake is adjustable?
5. What is the thickness capacity of the average bar folder?
6. The slip-roll forming machine has three rolls. Which of the three determines the radius of the curve?
7. What damage may be done if a seam is run through the rolls of a rotary machine?
8. What is the best check for the set-up of a sheet metal machine?
9. Give two reasons why a double hem is preferred to a single hem for some jobs.
10. How much material should be added when an edge is to be wired?
11. What is a snap bottom?
12. Why is the Pittsburgh lock often used on air ducts?

CHAPTER 3

GAS WELDING EQUIPMENT

1. Spell the name of the gas used as fuel for the welding flame?
2. The two gages attached to the oxygen regulator indicate what pressures?
3. How pure is welding oxygen?
4. What device acts as a "safety valve" for the oxygen bottle?
5. What parts of the welding outfit should be oiled?
6. What is the best method of testing hoses, connections, and fittings for gas leaks?

7. When is acetylene most dangerous?
8. When is oxygen dangerous?
9. The injector principle is used on which type of welding torch?
10. What property of metal has considerable influence on the selection of suitable welding torch tips?
11. What causes a flashback?
12. The welding of what metals requires the use of a slightly oxidizing flame?
13. Why is it dangerous to weld cored castings or closed containers?

CHAPTER 4

GAS WELDING (FERROUS)

1. What is the purpose of welding flux?
2. What is the basic skill required for good gas welding?
3. Why should you avoid including slag in a weld?
4. The strength of a weld depends on what three important factors?
5. What is the advantage of using a slightly carburizing flame for the average welding job?
6. What is the preferred edge bevel for butt-welding steel plate by the forehand method?
7. How thick should you make a tack weld on steel plate?
8. Why does backhand welding require a larger tip, for any given job, than the size required for forehand welding?
9. Why is it difficult to get a satisfactory weld on tool steel?
10. Why must a cast iron weldment be cooled slowly?

CHAPTER 5

OXYACETYLENE CUTTING

1. What effect does oxygen have when it is blown against red-hot steel?
2. The size cutting tip you select depends mostly on what factor?
3. Where should a fire watch be posted when you are using welding or cutting equipment on a bulkhead?
4. What are "drag lines"?
5. How should the torch be pointed when you are cutting off a piece of 5-inch pipe?
6. What happens to the preheating flames when the passages of the torch become clogged?
7. When is it permissible for you to cut a hole through a bulkhead or deck?

CHAPTER 6

BRAZING

1. What three general types of filler alloys are used for brazing?
2. Why is it necessary to thoroughly clean metal surfaces that are to be joined by brazing?
3. Most fluxes contain what common material?
4. For brazing, how far from the metal should you keep the tip of the inner cone of the flame?
5. What is the principal limitation of joints brazed with brass or silver solder?
6. Of the six grades of silver solder, which grades are most used?
7. While silver solder should not be used to fill bad joints, one grade can be used in emergency. Which grade is it?
8. A silver-soldered joint is usually satisfactory if the clearance of the fitted parts does not exceed what amount?
9. What is the commercial name of the flux ordinarily used with silver solder?
10. Why is it necessary that you have good ventilation when you are brazing or silver-soldering?
11. In what two ways is bronze filler metal superior to brass filler and silver solder alloys?

CHAPTER 7

ALUMINUM WELDING

1. Why is a fairly large tip required for welding aluminum?
2. Flux must be used when you are welding aluminum. Why?
3. What are the three methods commonly used to determine when wrought aluminum has almost reached the melting point?
4. What is the meaning of the term "hot-shortness"?

CHAPTER 8

ARC WELDING

1. Why is it more difficult to do arc welding aboard ship than ashore?
2. What is the approximate length of a good arc?
3. For straight polarity, the positive cable is connected to what?
4. What method can be utilized to minimize "arc blow"?
5. Name three conditions that indicate a poor weld?
6. What conditions may cause an arc-welder cable to get hot?
7. In what kind of a place should the arc-welding machine be stored when not in use?

CHAPTER 9

COPPERSMITHING

1. Why are wooden mallets used to shape copper sheets, pipe, and tubing?
2. Why not pour water into acid?
3. What is the principal advantage of using flanged pipe connec–tions?
4. How does a bulkhead flange differ from a regular flange?
5. Why are Van Stone flanges seldom used with copper pipe?
6. Copper that is being stretched or compressed must be annealed frequently. Why?
7. The halves for copper ball floats may be shaped over a ball. What other method is sometimes used?
8. Why should sand used for bending be perfectly dry?
9. What is likely to happen when a pipe bend wrinkle is folded over?
10. What clearance should the parts of a cup joint have if the joint is to be silver-soldered?
11. What is the principal advantage of using a sweep branch rather than a plain 45° or 90° branch?
12. Why are loops and bends used in piping?
13. When it is not practical to use a loop or a bend, what alternate device is used?
14. Why is a silver-soldered patch superior to a soft-soldered patch?
15. Copper-nickel alloy must be formed without heating. Why?

CHAPTER 10

WORKING WITH STEEL PIPE

1. Seamless steel pipe is only about 10 percent stronger than lap-welded pipe and is more expensive. Why, then, is seamless pipe preferred for most shipboard piping systems?
2. What is the difference between "pipe" and "tubing"?
3. You may see the symbol "XXH" used. What is its meaning?
4. A chill ring helps to aline two sections of pipe for welding. In what other ways does the chill ring improve the joint?
5. Heating devices used to heat pipe for bending aboard ship should be oil-burning torches. Why?
6. What is meant by "overbending" a pipe?

CHAPTER 11

FORGING

1. What effect does proper forging have on steel?
2. Wrought iron was formerly used extensively for the piping systems of Navy ships. What materials have largely replaced it?
3. What happens to the structure of steel when the steel is repeatedly reheated?
4. Why is a forged bend started away from the point of bend?
5. A ring to be made of ½″ stock must have an inside diameter of 3″. What length of stock is required for the ring if you allow ⅛″ for welding the joint?
6. Why is the top of a cold chisel heat-treated by a method different from that used for the cutting end?

CHAPTER 12

METALS—IRON AND STEEL

1. What kind of ore do all commercial ferrous metals come from?
2. What element makes the big difference between iron and steel?
3. A pushing stress is called "compression". What is the name applied to the pulling stress?
4. As you read reference books about iron and steel and other metals, you'll often see the abbreviation "psi". What is its meaning?
5. Why is black iron (ingot iron) so ductile?
6. How thick is a piece of 15-pound plate?
7. Name four simple methods you can use to approximate the carbon contents of a piece of steel.
8. What two standard systems are used to classify steels?
9. Would a cold chisel made of S.A.E. 1030 steel stand up in service?
10. What is the name of the hardness-testing machine that uses the "bouncing" principle?

CHAPTER 13

HEAT TREATMENT OF STEEL

1. What information should you have about a piece of steel before you attempt to heat-treat it?
2. Air drafts should not be allowed to strike hot metal. Why?
3. Which heat-treating process for steel requires an extremely slow rate of cooling?

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4. What is the quenching temperature for hardening S.A.E. 1090 steel?
5. Only experienced personnel should case-harden steel by the cyaniding process. Why?
6. Change 480° Centigrade to Fahrenheit degrees.
7. Change 617° Fahrenheit to Centigrade degrees.

CHAPTER 14

NON-FERROUS METALS

1. What is the meaning of the symbol "Pb"?
2. Why is copper used extensively for shipboard, low-pressure piping systems?
3. Brass is a non-ferrous alloy made up mostly of what two base metals?
4. Why is tin used to coat or plate galley utensils?
5. The fumes from heated zinc are extremely POISONOUS. The fumes of what other metal are also poisonous?
6. Copper-nickel alloy can be worked like copper with one important exception. What is that exception?
7. Which two wrought aluminum alloys are often designated for shipboard uses?

CHAPTER 15

FIGHTING FIRE

1. What size fire hose is used below decks?
2. What are the different settings of the all-purpose fire nozzle?
3. What is the duplex pressure proportioner?
4. Electrical fires should be extinguished with what type of equipment?
5. Can you change the canister of the patrol type oxygen breathing apparatus while you are fighting a fire in toxic air?
6. How should the safety lifeline be attached to a man?

CHAPTER 16

DAMAGE CONTROL

1. What communication circuits are indicated by the symbol JZ?
2. What is meant by the compartment symbol B–308E?
3. What doors and fittings are closed in material condition Y (yoke) on a large ship?
4. Why should wooden plugs be made of soft wood and left unpainted?

5. Plugs and wedges are not ordinarily driven into cracks. Why?
6. If riveted joints have pulled loose, should they be repaired by welding? Explain.
7. What is meant by shoring in damage control?

ANSWERS TO QUIZ

CHAPTER 1

THE METALSMITH'S WORK

1. Metalsmiths aboard ship are usually assigned to "A" Division of the Engineering Department.
2. A Metalsmith is ordinarily assigned to a damage control party (or repair party) because his regular duties fit him to help control and repair damage.

CHAPTER 2

SHEET METAL WORK

1. The thickness capacity of most squaring shears is 16 gage, or approximately 1/16″.
2. The amount of curve of a bend in sheet metal is designated by the radius of the curve.
3. Use the blowhorn stake to form the body of a funnel.
4. The upper jaw (clamping jaw) of the cornice brake may be adjusted "up and down" and "forward and backward."
5. The average bar folder has a thickness capacity of 22 gage.
6. The radius of the curve is controlled by adjustment of the back roll of the slip-roll forming machine.
7. If a seam is run through the rolls of a rotary machine, the seam will be cut or flattened and the rolls of the machine may be damaged.
8. The best check for a sheet metal machine set-up is to try it out on a piece of scrap stock of the same material and thickness as the stock you're going to use for the job.
9. The double hem is stronger than the single hem. It has no rough edges.
10. The allowance for a wired edge is equal to 2½ times the diameter of the wire to be used. Increase the allowance slightly for heavy gage metal.
11. When a disk is burred to form the bottom of a cylindrical container, it is called a snap bottom.
12. The Pittsburgh lock seam is frequently used on air ducts because the parts can be assembled easily on the job.

CHAPTER 3

GAS-WELDING EQUIPMENT

1. A-C-E-T-Y-L-E-N-E is the gas used as fuel for the welding flame.

2. One gage attached to the oxygen regulator indicates the bottle pressure; the other indicates the working pressure.
3. Oxygen used for welding is about 99.5 percent pure.
4. The fusible plug acts as a safety device for the oxygen bottle.
5. NONE of the welding equipment or accessories should ever be oiled.
6. To test hoses, connections, and fittings for gas leaks, use soapy water ONLY, while the equipment is under low gas pressure.
7. Acetylene is most dangerous when it is mixed with air or oxygen.
8. Oxygen is dangerous when it comes in contact with any highly combustible material, such as oil, grease, gasoline, or acetylene.
9. The low-pressure welding torch works on the injector principle.
10. The heat conducting ability of a metal influences the size tip to be used for welding that metal.
11. A flashback occurs when oxygen and acetylene become mixed too soon in the torch or hose and are ignited inside the torch.
12. Ordinarily, you will use an oxidizing flame only when you are welding or brazing copper and copper alloys, particularly brass and bronze.
13. Don't weld ANY container or casting which has spaces that are completely enclosed. If you do, the gases or liquids in the enclosed space will expand enough so that they may cause a violent explosion. Do not weld ANY containers that have been used to hold any inflammable material.

CHAPTER 4

GAS WELDING (FERROUS)

1. Flux is used to dissolve and prevent the formation of undesirable oxides and nitrides.
2. Torch manipulation is the basic skill required for good gas welding.
3. Slag causes a weld to be porous and weak.
4. Penetration, fusion, and amount of reinforcement are the important factors which determine the strength of a weld.
5. When you use a slightly carburizing flame you insure against having an oxidizing (burning) flame.
6. For forehand welding of steel plate, each edge should be beveled to 37½°—never more than 45°.
7. A tack weld on steel plate should be about ½ the thickness of the plate.
8. A larger tip is needed for backhand welding because the flame does not preheat the metal ahead of the weld as it does in forehand welding.

9. It's difficult to get satisfactory welds on tool steel because the welding heat destroys the special properties of the steel.
10. Slow cooling helps to prevent internal stresses and strains.

CHAPTER 5

OXYACETYLENE CUTTING

1. Red-hot steel is consumed (burned up) when oxygen is blown against it.
2. The thickness of the metal is the principal factor in selecting a cutting tip of the right size.
3. A fire watch should be posted on EACH SIDE of a bulkhead on which you are using welding or cutting equipment.
4. "Drag lines" are the lines left on metal that has been cut with a gas cutting torch.
5. In cutting off a piece of pipe, keep the torch flame pointed directly at the centerline of the pipe at all times.
6. Clogged torch passages cause the torch flames to become short.
7. Do not cut a hole through a bulkhead or deck until permission has been granted by the Damage Control Officer.

CHAPTER 6

BRAZING

1. Brass, bronze, and silver solder are the three general types of filler alloys used for brazing.
2. The metal must be clean so the filler metal can penetrate into the pores to form a good bond.
3. Most fluxes contain borax.
4. Keep the tip of the inner cone from ¼″ to ½″ away from the base metal. Never allow the inner cone tip to touch the base metal or the filler alloy.
5. Joints brazed with silver solder or brass should not be subjected to high temperatures—450°F. is about the limit.
6. The silver solders used most are Grades III and IV.
7. While silver solder should not be used to fill bad-fitting joints, Grade V can be used in emergency.
8. A silver-soldered joint is usually satisfactory if the clearance of the fitted parts does not exceed 0.005″.
9. Handy flux is ordinarily used with silver solder.
10. When brazing or silver-soldering, good ventilation is required to remove the poisonous fumes of hot flux and zinc.
11. Bronze filler metal is stronger and more heat resistant than brass filler metal or silver solder alloys.

CHAPTER 7

ALUMINUM WELDING

1. A comparatively large tip is required for aluminum welding because of the excellent heat conductivity of the metal.
2. The flux removes the aluminum oxide from the metal and helps to prevent the formation of additional oxide.
3. Three methods used to estimate the temperature of wrought aluminum are the pine stick method, the blue chalk method, and the scratching method.
4. A metal is said to be "hot-short" when it becomes weak and fragile at certain temperatures or in certain temperature ranges.

CHAPTER 8

ARC WELDING

1. Aboard ship the current fluctuates, thus making arc welding more difficult.
2. The length of a good arc is about equal to the diameter of the electrode rod or core.
3. For straight polarity, the positive cable is connected to the base metal.
4. You can minimize "arc blow" by shifting the ground cable clamp.
5. A poor weld is indicated by lack of fusion, porosity of the weld metal, and slag inclusions.
6. An arc-welder cable heats up when it is overloaded or when some of its strands have become parted.
7. Store the arc-welding machine in a dry, dust-free place. Electrical parts must be kept clean and dry.

CHAPTER 9

COPPERSMITHING

1. Wooden mallets are easily "made-to-order" to fit the job and they damage the copper less than metal tools.
2. When water is poured into acid, a violent boiling action results. This action may be strong enough to throw the acid out of the container and into your eyes. So always pour the acid INTO the water.
3. Piping sections that are flanged are easily removed for cleaning, repair, or replacement.

4. A regular flange has only one circle of holes. A bulkhead flange has two circular rows of holes.
5. Van Stone flanges are seldom used with copper pipe because the pipe is weakened where it is formed around the flange.
6. Copper "work hardens" when it is pounded or stretched and must be frequently softened by an annealing heat treatment.
7. The halves of a copper ball float can be shaped by pounding circular disks into a hollow form.
8. If wet sand were used in a pipe to be bent, the water would turn to steam when heated. The resultant expansion would blow out the end plugs or explode the pipe. Play safe and keep the sand dry.
9. A pipe bend wrinkle that is folded over will probably start a crack.
10. Clearance for a silver-soldered joint should be 0.002 to 0.003".
11. The sweep branch has less tendency than a plain 45° to 90° branch to check or block the flow of the liquids or gases conveyed by the pipe.
12. Loops and bends in piping absorb the stress caused by contraction and expansion due to temperature changes, gun recoil, bulkhead shifting, and engine vibration.
13. An expansion joint serves the same purpose as a loop or bend.
14. The silver-soldered patch is superior to the soft-soldered patch because it is stronger and more resistant to heat, shock, and vibration.
15. Copper-nickel alloy is "hot-short" when worked hot. It should be annealed and cooled before it is formed.

CHAPTER 10

WORKING WITH STEEL PIPE

1. Seamless pipe is preferred to lap-welded pipe because it can be bent and formed with less danger of cracking and splitting.
2. "Pipe" and "tubing" mean the same thing. However, when it is threaded it is usually called pipe.
3. Double Extra Heavy pipe is designated by the symbol "XXH".
4. The chill ring "backs up" the weld—makes it stronger—and prevents the formation of weld "icicles" on the inside of the pipe.
5. Heating equipment which burns fuel oil or Diesel oil is economical and the fuel is always available aboard ship. Avoid using the welding torch excessively because gas supply and storage is a big problem aboard ship.
6. "Overbending" a pipe means bending it past the desired angle and then bending it back. This method helps keep the area of the bend full and smooth.

CHAPTER 11

FORGING

1. The forging process, when properly carried out, improves the properties of the steel by refining the grain structure.
2. Wrought iron has been largely replaced by such alloys as copper-nickel, stainless steel, and other corrosion-resistant alloys.
3. Repeated reheating of steel enlarges the grains (increases porosity) and weakens the steel.
4. If a forged bend is started away from the point of bend, the bending strains will be more evenly distributed. Also, the cross-section of the piece will not be lessened so much if the bend is spread over a large area.
5. The stock must be 11⅛″ long. Here's the solution:

   $3'' + \frac{1}{4}'' + \frac{1}{4}'' = 3\frac{1}{2}''$ (the neutralaxis)
   $3\frac{1}{2}'' \times 3\ 1/7$ (pi) $= 11''$
   $11'' + \frac{1}{8}'' = 11\frac{1}{8}''$

6. The chisel head (pounding end) must be tough and shock-resistant. The cutting end must be extremely hard and only tough enough to prevent cracking and chipping.

CHAPTER 12

METALS—IRON AND STEEL

1. Commercial ferrous metals are made from iron ore.
2. The amount of carbon in a metal makes the big difference between iron and steel.
3. The pulling stress is known as tension.
4. "Psi" means POUNDS of force per SQUARE INCH.
5. Black iron has a high degree of ductility because it contains almost no carbon.
6. A piece of 15-pound steel plate is approximately ⅜″ thick.
7. You can estimate the carbon content of a piece of steel by filing, bending, denting, or grinding.
8. Steels are classified by the Society of Automotive Engineers (S.A.E.) and by the American Iron and Steel Institute (A.I.S.I.).
9. S.A.E. 1030 does not contain enough carbon to be hard enough for making any kind of cutting tools. S.A.E. 1080 will make a satisfactory cold chisel.

10. The Shore Scleroscope uses the bouncing principle for testing the hardness of metal.

CHAPTER 13

HEAT TREATMENT OF STEEL

1. Find out the approximate carbon content before you attempt to heat-treat a piece of steel.
2. Air drafts that strike hot metal may cause harmful internal strains which will result in warping and cracks.
3. Annealing requires an extremely slow rate of cooling.
4. The quenching temperature for hardening S.A.E. 1090 steel is 1450°F.
5. Cyanide fumes are extremely POISONOUS. That's why only experienced personnel should case-harden steel by the cyaniding process.
6. 480° Centigrade is equal to 896° Fahrenheit. Here's the solution to the problem—

$$\begin{array}{r} 480 \\ \times\ 9 \\ \hline 4320 \end{array} \qquad 4320 \div 5 = 864 \qquad \begin{array}{r} 864 \\ +\ 32 \\ \hline 896 \end{array}$$

7. 617°F. is equal to 325°C. It's figured like this—

$$\begin{array}{r} 617 \\ -\ 32 \\ \hline 585 \end{array} \qquad \begin{array}{r} 585 \\ \times\ 5 \\ \hline 2925 \end{array} \qquad 2925 \div 9 = 325$$

CHAPTER 14

NON-FERROUS METALS

1. "Pb" is the symbol for lead.
2. Copper is used extensively for low–pressure piping systems aboard ship because of its high resistance to corrosion, particularly salt-water corrosion. Also, it is easily formed and joined and has good shock resistance.
3. Brass is essentially an alloy of copper and zinc.
4. Tin is used to coat food-handling utensils because it is non-corrosive and non-poisonous.
5. The fumes of hot lead are extremely POISONOUS.
6. Copper-nickel must be worked cold because it is hot-short.
7. The wrought aluminum alloys 52S and 53S are used extensively by the Navy.

CHAPTER 15

FIRE FIGHTING

1. One and one-half inch fire hose is used below decks.
2. The all-purpose nozzle has three settings—for fog, for a solid stream, and for shut-off.
3. The duplex pressure proportioner is a portable double cylinder containing a mechanical foam solution, which is added to a water stream in the proper proportion.
4. The CO_2 (carbon-dioxide) extinguisher is used for electrical fires.
5. You must go out into safe fresh air to change the canister on the patrol type of oxygen breathing apparatus.
6. Attach the safety lifeline to the man's shoulders, preferably to a harness. Do not secure the line to the man's waist.

CHAPTER 16

DAMAGE CONTROL

1. The circuits for communication between damage control repair parties are given the symbol JZ.
2. The compartment symbol B–308E means that the compartment is located in the amidships division on the third deck, is numbered 08 (port side) and contains machinery.
3. Doors and fittings marked *X* and *Y* must be closed in material condition *Y* (yoke) on large ships.
4. Plugs made of soft wood stay in place better than those made of hard wood. They are left unpainted so they will soak up water and swell tight to form a seal.
5. Wedges or plugs should not be used in cracks because they tend to enlarge and spread the damage.
6. Riveted joints which have pulled loose should not be repaired by welding because the heat required may cause additional damage.
7. In damage control, shoring means the bracing of watertight bulkheads (or patches) so that they will withstand water pressure.

QUALIFICATIONS

METALSMITH THIRD CLASS

(A) PRACTICAL FACTORS.

(*a*) D–5204 (1), (Primary requirements of all petty officers.)

(*b*) TOOLS.—Demonstrate ability to use all hand tools, pneumatic tools, and machine tools commonly used in metal work shops, observing necessary safety precautions.

(*c*) PIPE FITTING.—Demonstrate ability to cut thread and fit pipe, to make joints in pipe lines, and to remove and replace pipe covering.

(*d*) FABRICATION.—Demonstrate ability to manufacture and repair simple sheet metal sections, such as ventilating ducts, lockers, etc.

(*e*) WELDING.—Demonstrate ability to perform simple oxyacetylene welding, brazing, and soldering, observing necessary safety precautions.

(*f*) TOOL REPAIR.—Demonstrate ability to sharpen, maintain, and repair hand tools.

(*g*) ANNEALING.—Demonstrate ability to anneal and work copper and brass.

(*h*) BLUEPRINTS.—Demonstrate ability to read and understand simple blueprints.

(B) EXAMINATION SUBJECTS.

(*a*) IDENTIFICATION OF METALS.—Be able to identify metal and structural shapes used aboard own ship. Know the kinds and types of piping used in various systems found on naval vessels.

(*b*) CARE OF TOOLS AND EQUIPMENT.—Thorough knowledge of the proper care and stowage of tools and equipment.

(*c*) FABRICATION.—Elementary knowledge of the fabrication of metal shapes, including ability to compute volumes for square and round tanks.

(*d*) WELDING.—Thorough knowledge of safety precautions for the handling of arc welding equipment.

(*e*) SOLDER.—Know the uses and the purposes of the various kinds of solder.

(*f*) HEAT TREATMENT.—Know the special pre-heating treatment required for metal objects known or suspected of having cores.

(*g*) GASES.—Be able to recognize bottled gases by their standard markings and know the safety precautions required for their use.

(*h*) FORGING.—Elementary knowledge of minor forging work.

(*i*) DAMAGE CONTROL.—Know the organization of damage control party to which assigned.

(*j*) D–5203. (General knowledge required of all men in the Navy.)

METALSMITH SECOND CLASS

(A) PRACTICAL FACTORS.

(*a*) TOOLS.—Demonstrate outstanding ability and skill in the use of all hand tools, pneumatic tools, and machine tools used by metalsmiths. Demonstrate a knowledge of the safety precautions involved.

(*b*) PIPE.—Demonstrate ability to make patches and repairs to pipes.

(*c*) COPPER SHAPES.—Demonstrate ability to make copper forms, shapes, floats, and balls.

(*d*) TESTS.—Demonstrate ability to make hydrostatic tests of pipe valves and fittings.

(*e*) WATERTIGHT DOORS.—Demonstrate ability to test and repair watertight doors, ports, and hatches.

(*f*) WELDING.—Demonstrate ability to qualify as a welder, third class. Demonstrate a thorough knowledge of the safety precautions to be observed before welding in any part of a ship.

(*g*) FORGING.—Demonstrate ability to perform minor forging work.

(*h*) BLUEPRINTS.—Demonstrate ability to read and understand all blueprints used by a metalsmith.

(*i*) D–5206.07 (1) (A). (Practical factors for M3/c)

(B) EXAMINATION SUBJECTS.

(*a*) USES OF METALS.—Know the uses of copper, brass, iron, steel, and other metals found on board ship. Know the uses of the various forms of stocks, bars, billets, and shapes.

(*b*) IDENTIFICATION OF METALS.—Be able to identify stock metals by their standard markings and to conduct simple tests to determine various metals and alloys.

(*c*) DAMAGE CONTROL.—General knowledge of damage control organization aboard own ship.

(*d*) DRAINAGE SYSTEM.—Show by diagram the drainage system in own ship.

(*e*) FORGING.—Working knowledge of the principles and practices of forging and tempering metal shapes.

(*f*) SAFETY PRECAUTIONS.—Know the safety precautions to be observed in working metals and in the use of forges.

(*g*) ALLOYS AND FLUX.—Know the uses and composition of various alloys and of flux.

(*h*) LAYING OUT.—Elementary knowledge of the procedure for laying out and performing metal working jobs aboard ship.

(*i*) WELDING.—Be familiar with welding nomenclature, definitions, and symbols, as set forth in GENERAL SPECIFICATIONS for INSPECTION of MATERIAL.

(*j*) PAINTING.—Know the current general instructions for painting.

(*k*) D–5206.07 (1) (B). (Examination subjects for M3/c).

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